Stormwater Management

FOR EASTERN WASHINGTON

Stormwater Management Manual for Eastern Washington

WASHINGTON STATE DEPARTMENT OF ECOLOGY

September 2004
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Washington State Department of Ecology
Water Quality Program

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Foreword

Objective of the Manual

Urban development causes significant changes in patterns of stormwater flow from land into receiving waters. Water quality can be affected when runoff carries sediment or other pollutants into streams, wetlands, lakes, and marine waters or into groundwater. Stormwater management can help to reduce these effects. Stormwater management involves careful application of site design principles, construction techniques and source controls to prevent sediment and other pollutants from entering surface or groundwater, treatment of runoff to reduce pollutants, and flow controls to reduce the impact of altered hydrology.

The objective of the *Stormwater Management Manual for Eastern Washington* (Manual) is to provide guidance in stormwater design and management for eastern Washington. The Manual aims to provide a commonly accepted set of technical standards, in addition to presenting new design information and new approaches to stormwater management. The Department of Ecology believes that when the standards and recommendations of this Manual are properly applied, stormwater runoff should generally comply with water quality standards and protect beneficial uses of the receiving waters. Ecology recognizes that individual circumstances vary greatly, and in some instances compliance with the Manual may not ensure compliance with water quality standards.

Background and Development of the *Stormwater Management Manual for Eastern Washington*

Many guidance manuals for stormwater have been written to address national, regional, and local characteristics and management needs. In Washington, several guidance manuals have been prepared, used, and updated to address regional and local requirements. Ecology published the *Stormwater Management Manual for Western Washington* in August 2001 as an update to a predecessor manual prepared in 1992 and initially proposed that the manual for western Washington could be updated to cover the entire state of Washington. Eastern Washington representatives requested that Ecology instead create a separate manual for the eastern portion of the state. Based upon these requests and upon recognition of the significantly different climate, hydrology and geology of eastern Washington, Ecology agreed to create a separate manual.

Discussions continued at various conferences, meetings and forums to determine the best method to accomplish this effort. A chartering meeting was held in June 2001 to formalize the structure and process for preparing the Manual for eastern Washington. The meeting was attended by more than 70 representatives of 17 cities, 11 counties and 5 federal and state agencies with interests in stormwater management in eastern Washington.

The chartering meeting established a ten-person Steering Committee with several alternate members to lead the overall effort; it also created two Subcommittees: one for leading the preparation of the Technical Stormwater Manual, and another for leading the preparation of a Model Municipal Stormwater Program. Ecology agreed to fund the hiring of a consultant team to support the development and preparation of the documents and to assist the Steering Committee and Subcommittees with meeting coordination, public involvement and related project tasks. Proposals were received by four consultant teams in October 2001; the Steering Committee selected the team lead by Tetra Tech/KCM of Spokane.

A project kick-off meeting was held on November 7, 2001 with members of the Steering Committee, Ecology, and the consultant team. The scope of work for the project and a proposed production schedule were prepared; a budget was prepared and the work began. A stakeholder workshop was held on November 29, 2001 to inform interested parties about the project efforts, the regulatory requirements, the schedule for meetings, and the document production format. After the introductory sessions, concurrent meetings of the Subcommittees were held to begin the development of the Manual and the Model Program. Meetings were held at least once per month to review drafts and updates for each chapter of each document. Periodic presentations were made to address special stormwater management issues. These efforts resulted in draft documents being submitted for public review in fall 2002.

Following the public comment period, the subcommittees reviewed all of the comments received on both of the documents and agreed to minor revisions to the Model Program and substantive revisions to the Manual. The final Model Program was published in September 2003. It is available at this website: www.ecy.wa.gov/biblio/0310076.html. The Manual underwent a second round of public review in summer 2003. This document results from the subcommittee's review of those comments.

Acknowledgement of the Eastern Washington Stormwater Management Steering Committee and Manual Subcommittee

Ecology would like to thank the members of the Eastern Washington Stormwater Management Steering Committee for their valuable commitment of time and leadership in leading the process to develop this Manual and the *Model Municipal Stormwater Program for Eastern Washington*.

Ecology would also like to thank the Eastern Washington Stormwater Manual Subcommittee participants for their valuable commitment of time

and energy in helping develop, review and shape the contents of this document.

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Organization of this Manual

Chapter 1: Introduction
The first chapter explains the need for a technical stormwater management manual, what the Manual is, and how the Manual is intended to be used. It provides the regulatory framework for the Manual.

Chapter 2: Core Elements for New Development and Redevelopment
This chapter describes the components of a successful stormwater management program. It provides the technical basis for eight specific elements of stormwater management that are required for most projects and describes the conditions under which one or more elements may or may not apply to a particular project.

Chapter 3: Preparation of Stormwater Site Plans
This chapter provides guidance for preparing the individual site plans upon which each project activity's success in managing stormwater will depend.

Chapter 4: Hydrologic Analysis and Design
This chapter identifies and describes the recommended methodologies for sizing and designing water quality treatment and flow control facilities.

Chapter 5: Runoff Treatment Facility Design
This chapter provides specific design information for runoff treatment systems, including infiltration treatment facilities and pre-treatment facilities required for Underground Injection Control (UIC) Program rule-authorized subsurface infiltration systems such as drywells.

Chapter 6: Flow Control Facility Design
This chapter provides specific design information for flow control facilities including detention, retention, evaporation, and infiltration systems.

Chapter 7: Construction Stormwater Pollution Prevention
This chapter identifies and describes best management practices for preventing pollution, particularly from erosion and sediment runoff, during the construction phase of a project.

Chapter 8: Source Control
The final chapter identifies and describes best management practices to prevent contamination of stormwater runoff.

Bibliography
Sources and references are listed for each chapter in a combined bibliography at the end of the Manual.

Glossary
Definitions of key terms used in the Manual are provided in the last section of the Manual.

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Chapter 1 - Introduction

1.1 Purpose and Scope

The objective of this Manual is to provide guidance in stormwater design and management for eastern Washington. The Manual aims to provide a commonly accepted set of technical standards in addition to presenting new design information and new approaches to stormwater management. These stormwater management practices, if properly applied at a project site, should protect water quality in the receiving waters (both surface and ground waters). Improperly managed stormwater runoff is one of the principal sources of water quality and habitat degradation in urban areas. A number of existing laws and regulations require that project proponents properly manage stormwater runoff to avoid adverse impacts to water quality and aquatic resources. This Manual is intended to provide technically sound and realistic guidance on how to properly manage stormwater runoff from individual project sites.

This Manual identifies eight Core Elements for managing stormwater runoff from new development and redevelopment projects of all sizes. The Manual also provides guidance for preparation and implementation of stormwater site plans. The requirements of the Core Elements are generally satisfied by the application of Best Management Practices (BMPs) selected from Chapters 5 through 8 of this Manual. Projects that follow this approach will apply reasonable, technology-based BMPs and water quality-based BMPs to reduce the adverse impacts of stormwater.

This Manual is applicable to all types of land development. BMPs for residential, commercial and industrial development and road projects are included. A Manual with a more specific focus, such as a Highway Runoff Manual or a stormwater manual adopted by a local jurisdiction, may provide more appropriate guidance to the project proponent.

The Manual is limited in scope for addressing environmental problems caused by urbanization. The Manual does not include site development standards or limit where development should be allowed. Project by project management of stormwater runoff from new development and redevelopment alone will not correct existing water quality and instream habitat problems. The engineered runoff treatment and flow control facilities recommended in this Manual can reduce the adverse impacts of development, but such facilities cannot remove sufficient pollutants to replicate the pre-development water quality, nor can they replicate the natural functions of the watershed that existed before development.

This Manual is applicable to all of eastern Washington, including the area bounded on the west by the Cascade Mountains crest; on the north by the Canadian border; on the east by the Idaho border; and on the south by the Oregon border. At the southern end of Washington's Cascade Mountain range where the crest does not follow county borders, this Manual is applicable to all of Yakima and Klickitat Counties.

1.1.1 The Manual's Role as Technical Guidance

The *Stormwater Management Manual for Eastern Washington* is not a regulation. The Manual does not have any independent regulatory authority and it does not establish new environmental regulatory requirements. Current law and regulations require project proponents to design, construct, operate, and maintain stormwater treatment systems that prevent pollution of State waters. The Manual is a guidance document which provides local governments, state and federal agencies, developers and project proponents with a set of stormwater management practices. If these practices are implemented correctly, they should result in compliance with existing regulatory requirements for stormwater – including compliance with the federal Clean Water Act, federal Safe Drinking Water Act and state Water Pollution Control Act.

The purpose of this Manual is to provide technical guidance on measures to control the quantity and quality of stormwater runoff from new development and redevelopment projects. These measures are considered to be necessary to achieve compliance with state water quality standards and to contribute to the protection of the beneficial uses of the receiving waters (both surface and ground waters). Stormwater management techniques applied in accordance with this Manual are presumed to meet the technology-based treatment requirement of state law to provide all known available and reasonable methods of treatment, prevention and control (AKART; RCW 90.52.040 and RCW 90.48.010).

This technology-based treatment requirement does not excuse any discharge from the obligation to apply additional stormwater management practices as necessary to comply with State water quality standards. The State water quality standards include: Chapter 173-200 WAC, Water Quality Standards for Ground Waters of the State of Washington; Chapter 173-201A, Water Quality Standards for Surface Waters of the State of Washington; and Chapter 173-204, Sediment Management Standards. Additional treatment to meet those standards may be required by federal, state, or local governments.

Following this Manual is not the only way to properly manage stormwater runoff. A project proponent may choose to implement other practices to protect water quality; but in this case, the project proponent assumes the responsibility of providing technical justification that the chosen practices will protect water quality (see Section 1.1.3, Presumptive versus Demonstrative Approaches to Protecting Water Quality below).

1.1.2 More Stringent Measures and Retrofitting

Federal, state, and local government agencies with jurisdiction can require more stringent measures that are deemed necessary to meet locally established goals, state water quality standards, or other established natural resource or drainage objectives. Water cleanup plans or Total Maximum Daily Loads (TMDLs) may identify more stringent measures needed to restore water quality in an impaired water body.

This Manual is not a retrofit manual, but it can be helpful in identifying options for retrofitting BMPs to existing development. Retrofitting stormwater BMPs into existing developed areas may be necessary to meet federal Clean Water Act and state Water Pollution Control Act (Chapter 90.48 RCW) requirements. In retrofit situations there frequently are site constraints that make the strict application of these BMPs difficult. In these instances, the BMPs presented here can be modified using best professional judgment to provide reasonable improvements in stormwater management.

1.1.3 Presumptive versus Demonstrative Approaches to Protecting Water Quality

Wherever a discharge permit or other water-quality-based project approval is required, project proponents may be required to document the technical basis for the design criteria used to design their stormwater management BMPs. This includes: how stormwater BMPs were selected; the pollutant removal performance expected from the selected BMPs; the scientific basis, technical studies, and(or) modeling which supports the performance claims for the selected BMPs; and an assessment of how the selected BMP will comply with state water quality standards and satisfy state AKART requirements and federal technology-based treatment requirements.

The Manual is intended to provide project proponents, regulatory agencies, and others with technically sound stormwater management practices which are *presumed* to protect water quality and instream habitat – and meet the stated environmental objectives of the regulations described in this chapter. Project proponents always have the option of not following the stormwater management practices in this Manual. However, if a project proponent chooses not to follow the practices in the Manual then the project proponent may be required to individually *demonstrate* that the project will not adversely impact water quality by collecting and providing appropriate supporting data to show that the alternative approach is protective of water quality and satisfies state and federal water quality laws.

Figure 1.1 graphically depicts the relation between the *presumptive approach* (the use of this Manual) and the *demonstrative approach* for achieving the environmental objectives of the standards. Both the presumptive and demonstrative approaches are based on best available science and result from existing federal and state laws that require stormwater treatment systems to be properly designed, constructed, maintained, and operated to: all known available and reasonable methods to prevent and control the pollution of the waters of the state

Figure 1.1 – Relation between environmental science and standards in stormwater regulations. Both the presumptive and demonstrative approaches are based on using best available science to protect water quality. See the glossary for definitions.

STANDARDS

Water Pollution Control Act

(Chapter 90.48 RCW)

Discharges to state waters shall not cause pollution, defined as alteration of the physical, chemical or biological properties of state waters which would impair beneficial uses. Requires use of all known and reasonable methods to prevent and control pollution (AKART).

Clean Water Act

Restore and maintain the chemical, physical, and biological integrity of the nation's waters.

- State water quality standards (water-quality based treatment requirements)
- Federal technology-based treatment requirements
- National Pollutant Discharge Elimination System (NPDES) permits
- 303(d) impaired waterbody list and water clean-up plans

Others

Hydraulics Code

- Hydraulic Project Approvals (HPAs)

Safe Drinking Water Act

- Underground Injection Control (UIC) program

Endangered Species Act

- Properly functioning conditions

Presumptive Approach

The Stormwater Management Manual for Eastern Washington provides a default set of stormwater practices based on current science which satisfy State and Federal stormwater requirements.

Considerations:

- More predictable, practices are approved across jurisdictions
- Costly studies, etc. are not required as they may be under the demonstrative approach

Demonstrative Approach

Project sponsor and approval agency individually review and condition proposed projects to meet federal and state stormwater standards based on current science.

Considerations:

- Lacks predictability and can be very time consuming
- For large, complex projects may reduce costs and/or improve environmental protection

Hydrology

- When native vegetation is removed and replaced with impervious surfaces (roads or buildings) there is an increase in stormwater runoff and a decrease in summer base flows.
- Increased flows lead to increased flooding and stream bank and stream bed erosion.
- Unless mitigated, adverse high flow impacts occur at even low levels of urban development: 4% to 10% total impervious area.
- Transportation infrastructure (including parking areas) represents between 50% and 75% of the impervious surface area within any single watershed.

Water Quality

- More than a third of the state's urban streams, creeks, and embayments are impaired due to stormwater runoff.
- Stormwater runoff from construction activities can contain large amounts of sediments and suspended solids which are harmful to fish and other aquatic life.
- Untreated stormwater from roads and urban areas can adversely impact water quality due to sediments, toxic metals, pesticides, herbicides, oils and greases, and possible human pathogens including fecal coliform bacteria.
- Untreated stormwater runoff from roads and urban areas can be toxic to aquatic life including fish.

SCIENCE

1. Prevent pollution of state waters and protect water quality, including compliance with state water quality standards;
2. Satisfy state requirements for all known available and reasonable methods of prevention, control and treatment (AKART) of wastes prior to discharge to waters of the State; and
3. Satisfy the federal technology based treatment requirements under 40 CFR part 125.3.

Under the demonstration approach, the timeline and expectations for providing technical justification of stormwater management practices will depend on the complexity of the individual project and the nature of the receiving environment. In each case, the project proponent may be asked to document to the satisfaction of the permitting agency or other approval authority that the practices which have been selected for the individual project will result in compliance with the water quality protection requirements of the permit or other local, state, or federal water-quality-based project approval condition(s). This approach may be more cost effective for large, complex, or unusual types of projects.

Project proponents who choose to follow the stormwater management practices contained in approved stormwater technical manuals are presumed to have satisfied this demonstration requirement and do not need to provide technical justification to support the selection of BMPs for the project. Following the stormwater management practices in this Manual means adhering to the guidance provided for proper selection, design, construction, implementation, operation, and maintenance of BMPs. Approved stormwater technical manuals include this Manual and other equivalent stormwater management guidance documents approved by Ecology. This approach will generally be more cost effective for typical development and redevelopment projects.

1.1.4 Comparison of the Stormwater Management Manuals for Eastern and Western Washington

Both the *Stormwater Management Manual for Eastern Washington* (SWMMEW) and the *Stormwater Management Manual for Western Washington* (SWMMWW) are based on the same standard: protecting water quality. The manuals are organized differently, with the SWMMEW comprised of eight chapters and the SWMMWW comprised of five volumes. The eight Core Elements of the SWMMEW include the same goals as the ten Minimum Requirements of the SWMMWW, but again, the organization is different. Differences in climate, hydrology, and the current understanding of rainfall-runoff relationships on the two sides of the state led to different approaches in the two manuals for designing and sizing treatment facilities. Special considerations for the arid climate and for freezing weather are included in the SWMMEW but not in the SWMMWW. As we gain better understanding of the natural systems on both sides of the state and as approaches to managing stormwater continue to improve, both manuals will be updated.

1.2 Effects of Urbanization

Managing stormwater may not seem necessary in arid and semi-arid regions where rainfall is generally a welcome event. However, the quality and habitat function of receiving waters in arid and semi-arid climates are affected by pollutants carried by stormwater runoff and by the changes in the patterns of runoff from the land following development. Hydrologic and water quality changes caused by urbanization can result in irreversible changes to the biological systems that were supported by the natural hydrologic system.

1.2.1 Water Quality Changes

Although few data are available specifically from eastern Washington, studies across the nation have found that urbanization causes increases in the types and quantities of pollutants in receiving waters. Regardless of the climatic setting, runoff from urban areas has been shown to contain many different types of pollutants, depending on the nature of the activities in those areas.

- The runoff from roads and highways is contaminated with pollutants from vehicles, and typical pollutants in road runoff include: oil and grease, polynuclear aromatic hydrocarbons (PAHs), lead, zinc, copper, cadmium, sediments (soil particles), and road salts and other anti-icers.
- Runoff from industrial areas typically contains even more types of heavy metals, sediments, and a broad range of man-made organic pollutants, including phthalates, PAHs and other petroleum hydrocarbons.
- Runoff from commercial areas contains concentrated road-based pollutant runoff and may also contain other pollutants typical of industrial and/or residential areas.
- Residential areas contribute the same road-based pollutants to runoff, as well as herbicides; pesticides; nutrients (from fertilizers and animal wastes); and bacteria, viruses and other pathogens (from animal wastes).

The pollutants in urban runoff can be dissolved in the water column or can be attached to solid particles that settle in streambeds, lakes, or wetlands. All of these contaminants can impair the beneficial uses of the receiving waters (both ground and surface waters). Metals are of particular concern for discharges to surface waters due to the sensitivity of aquatic life to fairly low concentrations, especially copper and zinc. Pesticides and PAHs are of particular importance to discharges to groundwater.

Table 1.1 shows typical concentrations of a limited number of pollutants found in urban stormwater runoff. The pollutant concentrations in stormwater runoff from arid watersheds tend to be higher than that of humid watersheds, since rain events are infrequent and pollutants have more time to accumulate on impervious surfaces. Pervious areas in arid and semi-arid regions also tend to produce higher sediment and organic carbon concentrations because the sparse vegetative cover does little to prevent soil erosion in uplands and along channels when it does rain.

Table 1.1 – Mean concentrations of selected pollutants in urban stormwater runoff across the United States and in arid and semi-arid regions.

Source: several studies summarized in Watershed Protection Techniques, Vol. 3 No. 3, March 2000.

Location	Total Suspended Solids (mg/L)	Total Copper (ug/L)	Total Zinc (ug/L)	Total Lead (ug/L)	Total Phosphorus (ug/L)
National Average	78	14	162	68	320
Phoenix, AZ	227	47	204	72	410
Boise, ID	116	34	342	46	750
Denver, CO	384	60	350	250	800
San Jose, CA	258	58	500	105	830
Dallas, TX	663	40	540	330	780

Table 1.2 shows typical concentrations of a limited number of pollutants from stormwater runoff generated by different land uses.

Table 1.2 – Mean concentrations of selected pollutants in stormwater runoff from different land uses in the state of Oregon.

Note: In-pipe industry means the samples were taken in stormwater pipes. Instream industry means the samples were taken in streams flowing through industrial areas. Samples for all other categories were taken from within stormwater pipes.

Source: Strecker et al, *1997.*

Land Use	Total Suspended Solids (mg/L)	Total Copper (ug/L)	Dissolved Copper (ug/L)	Total Zinc (ug/L)	Total Phospho-rus (ug/L)
In-pipe industry	194	53	9	629	633
Instream industry	102	24	7	274	509
Transportation	169	35	8	236	376
Commercial	92	32	9	168	391
Residential	64	14	6	108	365
Open	58	4	4	25	166

Table 1.3 shows typical concentrations of a limited number of pollutants in highway runoff. These pollutants were detected in 46% to 100% of the samples collected for 102 sites with AADT =<30,000 and 93.5% to 100% of the samples collected for 231 sites with AADT >30,000. In this study,

concentrations of cadmium copper, lead, and zinc frequently exceed state surface water quality standards for the protection of aquatic life regardless of whether the annual average daily traffic count on the road was more or less than 30,000; and concentrations of arsenic, chromium, lead, and coliform bacteria frequently exceed state groundwater quality standards.

Table 1.3 – Mean concentrations of selected pollutants in highway stormwater runoff in the state of California.

Source: California Department of Transportation, 2002.

Annual Average Daily Traffic (AADT)	Total Suspended Solids (mg/L)	Dissolved & Total Cadmium (ug/L)	Dissolved & Total Copper (ug/L)	Dissolved & Total Lead (ug/L)	Dissolved & Total Zinc (ug/L)
Less than or equal to 30,000	160	0.13	6.9	1.3	33
		0.32	16	12	90
Greater than 30,000	160	0.30	16	7.6	93
		0.89	39	64	260

The Washington State Department of Transportation submitted data in to Ecology in its fourth year NPDES Program Summary (Molash, 1999) for two state highways: SR8 in Thurston County, with an average daily traffic (ADT) count of 18,000; and SR5 in Clark County, with an ADT of 101,000. For copper, the acute water quality standard was exceeded in 40 percent of the samples collected on each highway, with the concentrations in those samples ranging from 1.1 times the standard to 8.5 times the standard. For zinc, the acute water quality standard was exceeded in 60 percent of the samples collected on SR5 and in 70 percent of the samples collected on SR8, with the concentrations in those samples ranging from 1.3 times the standard to 14 times the standard.

While instream dilution of the higher concentrations from any single project might prevent impairment of the beneficial uses of a water, capacity does not exist in most urban streams to dilute the discharges from all of the sources in the watershed, and the cumulative effect of all of the discharges in the watershed is much more likely to impair the beneficial uses of the receiving water.

Urbanization may also cause changes in water temperature. Stormwater heated from impervious surfaces and exposed treatment and detention ponds may be discharged to streams with less riparian vegetation for shade. Urbanization also reduces recharge of groundwater, a source of cool water contributions to stream flows.

Regardless of the eventual land use conversion, the sediment load produced by a construction site can increase turbidity in the receiving water. Fine sediments can be deposited over the natural sediments of the receiving water and degrade fish spawning areas and instream habitat for other aquatic life.

This Manual provides guidance on runoff treatment practices for reducing the impacts of pollutant-laden stormwater from individual sites through source control, construction stormwater pollution prevention, and water quality treatment Best Management Practices (BMPs). Section 1.4.2 provides the background of developing source control BMPs; Core Element #3 in Chapter 2.2.3 defines the requirements for applying these BMPs. Section 1.4.3 provides the background of developing runoff treatment BMPs; Core Element #5 in Chapter 2.2.5 defines the requirements for applying these BMPs. Core Element #2 in Chapter 2.2.2 and all of Chapter 7 are devoted to construction stormwater pollution prevention.

1.2.2 Hydrologic Changes

Just as the landscape of eastern Washington includes prairies, pine forests, the shrub-steppe, channeled scablands, and vast areas of irrigated and dry land agriculture, the hydrology of streams in eastern Washington varies tremendously. Average annual precipitation varies from 6 to more than 60 inches. Streambed material varies from basalt rock to highly erodible loess soils. Many streams flow only during the relatively wet winter and spring seasons or only during a runoff-producing rainstorm or snowmelt event. The hydrology of other streams has been altered by seasonal irrigation practices.

Regardless of the hydrologic and geologic setting, streams can be impacted by urbanization of their watersheds. As development occurs, land is cleared and impervious surfaces such as roads, parking lots, rooftops, and sidewalks are added. Roads are cut through slopes and low spots are filled. The natural soil structure is lost due to grading and compaction during construction. Drainage patterns are irrevocably altered. Maintained landscapes that have much higher runoff characteristics often replace the natural vegetation. The accumulation of these changes may affect the natural hydrology by:

- Increasing the peak volumetric flow rates of runoff,
- Increasing the total volume of runoff,
- Decreasing the time it takes for runoff to reach a natural receiving water,
- Increasing stream velocities,
- Reducing groundwater recharge,
- Increasing the frequency and duration of high stream flows,
- Increasing inundation of wetlands during and after wet weather, and
- Reducing stream flows and wetland water levels during the dry season.

Figure 1.2 illustrates some of these hydrologic changes. As a consequence of these changes in hydrology, stream channels may experience both increased flooding and reduced base flows. Natural riffles, pools, gravel bars, and other areas may be altered or destroyed. Increased channel erosion, loss of hydraulic complexity, degradation of habitat, and changes in the composition of species present in receiving waters may follow.

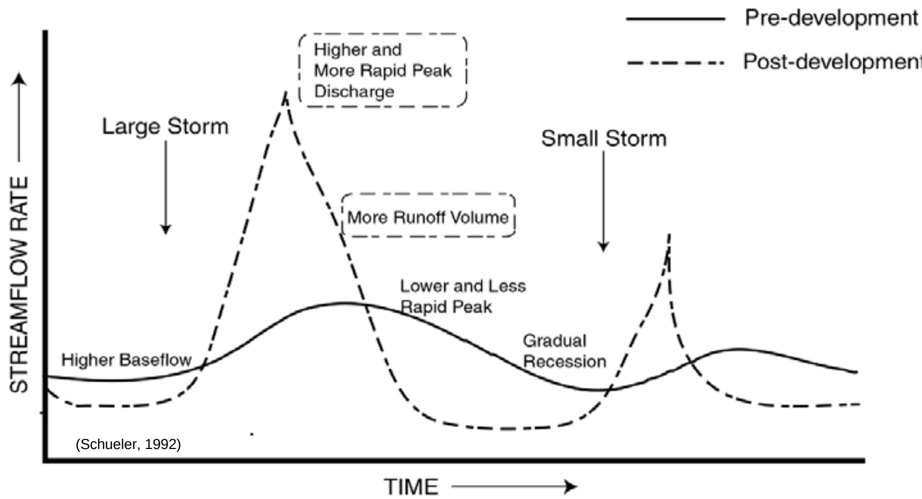

Figure 1.2 – Changes in hydrology following development

These changes do not result from any one project; they are the cumulative effect of all of the development in a watershed.

From a stream morphology standpoint, smaller flood events that approximate bankfull conditions and occur naturally every year or two (1.5 to 2-year frequency) are the most influential discharges and most easily changed with added urban runoff. It is these smaller flood events that shape the channel and are referred to as "effective flows" because over time they move the most sediment and transform the dimensions of a stream channel. When effective flows increase in size, duration, and frequency, the most common impact is changes in channel morphology to accommodate the rise in erosive energy delivered to receiving streams on an annual basis.

Although specific data and studies for eastern Washington are not currently available, research in streams in arid, semi-arid, and humid climate settings has shown that this accommodation commonly takes place by widening and down cutting of the streambed, damaging habitats and potentially reducing biologic diversity. Research has shown that as developed impervious areas reach five percent of land cover within a watershed, the connection between runoff from impervious areas and channel response through erosion begins to occur (Hajda, 1999; Hollis, 1975; and Booth, 1991).

Erosion problems from an aquatic ecosystem perspective are much more subtle than from an engineering perspective: streambank undercutting and failures occur long after changes to the habitat function of the streambed.

Stream channel erosion control can be accomplished by constructing BMPs that detain runoff flows and also by physical stabilization of eroding stream banks. Both types of measures may be necessary in urban streams, but only the former is covered in this Manual.

When comparing the pre-developed or existing conditions hydrograph with the proposed development condition hydrograph, the concern is not limited to the peak flow events; mitigating the duration of the flood flows is also important for stream channel stability and habitat. Detention basins that match peak runoff directly contribute more water to a stream over a longer period of time and extend the length of time the peak discharge rate is moving sediments in the streambed. The cumulative impacts of many detention basins operating in a watershed and merging downstream further compound flooding and erosion problems.

Because these changes are the cumulative result of development in a watershed, most new development in most watersheds must control flows. The intent of flow control is to prevent increases in the stream channel erosion rates that are characteristic of natural conditions by releasing runoff from the proposed development condition in a manner that delivers approximately the same amount of erosive energy to the stream as it received under pre-developed or receives under existing conditions.

Flow control in this Manual is targeted to smaller water bodies, especially first to third order streams or water bodies with contributing watershed areas of less than 100 square miles. These streams are most susceptible to changes in runoff patterns caused by development. In larger water bodies, the location of the development activity plays a greater role: in general, development that occurs nearer to a large stream channel and that does not encroach on the natural flood plain has less of an effect than development activities in the upper watershed – which are instead likely to impact smaller tributary stream channels.

This Manual provides guidance on stormwater management practices for controlling excess runoff volume from individual sites through flow control Best Management Practices (BMPs). Section 1.4.4 provides the background of developing these BMPs; Core Element #6 in Chapter 2.2.6 defines the requirements for applying these BMPs.

1.3 Relationship of this Manual to Federal, State and Local Regulatory Requirements

This Manual is one tool in the efforts to manage and reduce the impacts of urban stormwater discharges. At the date of publication of this Manual, several regulatory programs and permits exist that may directly or indirectly require a project proponent to properly manage stormwater.

1.3.1 Applicable Federal and State Regulations

The federal Clean Water Act, the federal Safe Drinking Water Act, and the state Water Pollution Control Act (RCW 90.48) are the primary federal and state regulations that directly apply to management of stormwater discharges. These laws are aimed at protecting water quality by controlling the amount of pollutants discharged to surface and ground waters. Other regulatory programs such as the federal Endangered Species Act and state Hydraulics Act also commonly require project proponents to properly manage stormwater to protect water quality and habitat. Specific permitting programs and other situations where stormwater management may be required by law are detailed in the following sections.

1.3.2 NPDES and State Waste Discharge Stormwater Permits for Municipalities

In Washington State, the cities of Seattle and Tacoma; King, Pierce, Snohomish, and Clark counties; and the Washington State Department of Transportation facilities within those jurisdictions have been subject to U.S. Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Phase I Stormwater Regulations (40 CFR Part 122). EPA adopted NPDES Phase II stormwater regulations in December 1999. Those rules identify additional municipalities that are subject to NPDES municipal stormwater permitting requirements. In eastern Washington there are no Phase I communities; Ecology has determined that fifteen cities and eight counties in the five census-defined urbanized areas of eastern Washington are subject to the requirements. The census-defined urbanized areas in eastern Washington are: Clarkston, Spokane, Tri-Cities, Wenatchee, and Yakima. Another five (Ellensburg, Moses Lake, Pullman, Sunnyside, and Walla Walla) or more additional municipalities may be subject to the requirements, depending upon an analysis that Ecology must perform. Federal regulations required that Phase II permits be issued by December 2002 and that designated Phase II communities submit an application for permit coverage by March 2003.

The federal regulations specify minimum measures for municipal stormwater programs for compliance with the Phase II rules. One of those measures is the adoption of a program for “post-construction stormwater management in new development and redevelopment.” Another is a program for “construction site stormwater runoff control.” This Manual provides technical guidance for projects to comply with municipal stormwater requirements in these two areas. For additional information on the Phase II municipal permit and the minimum control measures, see Ecology’s website and Ecology publication 03-10-076: *Model Municipal Stormwater Program for Eastern Washington*.

Local jurisdictions covered under the Phase II Municipal Stormwater NPDES Permit must apply this Manual or an approved equivalent to their own capital improvement and other public works projects. All local jurisdictions should work to identify and prioritize stormwater management actions that will effectively protect local water quality.

In Washington State under RCW 90.48, all permits for discharges of pollutants apply to discharges to groundwater as well as discharges to surface water. Jurisdictions applying for coverage under the Phase II Municipal Stormwater NPDES Permit will receive a combined NPDES State Waste Discharge Permit. At the time of publication of this Manual, Ecology was proposing that the Phase II Municipal Stormwater NPDES Permits would address discharges to groundwater. Where there are existing regulatory programs that address discharges to groundwater, Ecology would defer to those programs rather than duplicate or add new requirements. For discharges to groundwater that are covered under the Underground Injection Control (UIC) program (see section 1.3.5), Ecology would defer to the UIC program for the control of those discharges and not regulate those discharges under the Phase II Municipal Stormwater NPDES Permits.

1.3.3 Industrial Stormwater General Permit
(NPDES and State Waste Discharge Baseline General Permit for Stormwater Discharges Associated With Industrial Activities)

Businesses subject to the Industrial Stormwater General Permit have to prepare and implement a Stormwater Pollution Prevention Plan in accordance with the terms of that permit. The general permit, which was reissued August 2002, requires a description and implementation of operational source control BMPs and structural source control BMPs as applicable to their industrial activity. Additionally, application of erosion and sediment control BMPs, flow control BMPs, and treatment BMPs is required if necessary to address an erosion, flow, or pollution problem.

This Manual can be used to select and design stormwater BMPs for industrial sites eastern Washington.

1.3.4 Construction Stormwater General Permit
(NPDES and State Waste Discharge General Permit for Stormwater Discharges Associated With Construction Activity)

Operators of construction activities are required to seek coverage under the Construction Stormwater General Permit if the activity results in the disturbance of five acres or greater (including clearing, grading, and excavation activities) and also has a discharge of stormwater to a surface water and/or to a storm drain used to convey water to a surface water.

Beginning March 10, 2003, the U.S. Environmental Protection Agency's Phase II Rule (Federal Register, Vol.64, No. 235, pages 68722-68852) requires operators of "Small Construction" activities disturbing greater than one acre of land to obtain an NPDES permit before discharging stormwater to a surface water or storm drain that discharges to a surface water.

The Construction Stormwater General Permit requires the development and implementation of a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP must detail the various Best Management Practices (BMPs) that will be used during construction to prevent erosion and sedimentation that could impact downstream water quality. This Manual may be used by project proponents and others in the development of the SWPPP and in the selection, design, and application of erosion and sediment runoff control BMPs.

1.3.5 Underground Injection Control (UIC) Program

One of the provisions of the federal Safe Drinking Water Act is to protect underground sources of drinking water (USDW). The Underground Injection Control (UIC) program was established to protect USDW by regulating the discharges of fluids into the subsurface by underground injection wells. In 1984 Ecology adopted Chapter 173-218 WAC to implement the program.

Subsurface infiltration systems, such as drywells, are classified as Class V injection wells in the EPA's federal UIC program. The two requirements of the UIC program are:

- A non-endangerment performance standard must be met, prohibiting discharges that allow movement of fluids containing contaminants into potential underground sources of drinking water, and
- All UIC facility owners/operators must provide inventory information by registering the facilities.

Under the federal UIC regulations, the definition of an underground injection well is a bored, drilled, or driven shaft whose depth is greater than the largest surface dimension; or a dug hole whose depth is greater than the largest surface dimension; or an improved sinkhole; or a subsurface fluid distribution system which includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground. Examples of a UIC well or a subsurface infiltration system are drywells, drain fields, and pipe or french drains and other similar devices that discharge to ground.

Note: *Ecology is proposing to revise the existing UIC rule (Chapter 173-218 WAC). The proposed changes to the rule include rule authorization for properly managed stormwater from defined sources to be discharged to subsurface infiltration systems. Proper management would be based on following applicable best management practices as described in Ecology's current regional stormwater manuals or an approved equivalent manual. This Manual will be the applicable manual for eastern Washington. For more information about the rule revision contact Mary Shaleen-Hansen at* *maha461@ecy.wa.gov or (360) 407-6143, or visit Ecology's website at* http://www.ecy.wa.gov/programs/wq/grndwtr/uic

1.3.6 Endangered Species Act

Project proponents planning to discharge stormwater into bodies of water that provide habitat for threatened or endangered species are expected to properly manage their stormwater. This Manual may be used by project proponents to satisfy federal Endangered Species Act requirements as identified by the federal service agencies.

1.3.7 Section 401 Water Quality Certifications

For projects that require a fill or dredge permit under Section 404 of the Clean Water Act, Ecology must certify to the U.S. Army Corps of Engineers that the proposed project will not violate water quality standards, including state sediment standards. In order to make such a determination, Ecology may do a more specific review of the potential impacts of a stormwater discharge from the construction phase of the project and from the completed project. As a result of that review, Ecology may condition its certification to require:

- Application of the Core Elements and BMPs in this Manual; or
- Application of alternative requirements determined to be necessary to comply with state water quality standards.

1.3.8 Hydraulic Project Approvals (HPAs)

Under Chapter 77.55 RCW, the Hydraulics Act, the Washington State Department of Fish and Wildlife has the authority to require actions when stormwater discharges related to a project would change the natural flow or bed of state waters. The implementing mechanism is the issuance of a Hydraulics Project Approval (HPA) permit. In exercising this authority, the Department of Fish and Wildlife may require:

- Compliance with the provisions of this Manual; or
- Application of alternative requirements that are determined to be necessary to meet their statutory obligations to protect fish and wildlife.

1.3.9 Aquatic Lands Use Authorizations

As the steward of public aquatic lands, the Department of Natural Resources (DNR) may require a stormwater outfall to have a valid use authorization and to avoid or mitigate impacts to natural resources. Through its use authorizations, which are issued under authority of Chapter 79.90 through 96, and in accordance with Chapter 332-30 WAC, DNR may require:

- Compliance with the provisions of this Manual; or

- Application of alternative requirements that are determined to be necessary to meet their statutory obligations to protect the quality of the state's aquatic lands.

1.3.10 Requirements Identified through Watershed/Basin Planning or Total Maximum Daily Loads

A number of the requirements of this Manual can be superseded by the adoption of ordinances and rules to implement the recommendations of watershed plans or basin plans. Local governments may initiate their own watershed or basin planning processes to identify more stringent or alternative requirements. They may choose to develop a watershed plan in accordance with the Watershed Management Act (Chapter 90.82 RCW) that includes water quality and habitat elements. They may also choose to develop a basin plan in accordance with Chapter 400-12 WAC. As long as the actions or requirements identified in those plans and implemented through local or state ordinances or rules comply with applicable state and federal regulations (e.g., the Clean Water Act), they can supersede the requirements in this Manual. The determination of whether such local requirements comply with federal and state statutes must be made by the regulatory agency or agencies responsible for implementing those regulations.

Any requirement of this Manual may also be superseded or added to through the adoption of actions and requirements identified in a Total Maximum Daily Load (TMDL) that is approved by the EPA. However, it is likely that many TMDLs will require use of the BMPs in this Manual.

According to the federal NPDES Phase II rules, Ecology may include requirements in municipal stormwater permits including programmatic activities and other actions identified in completed TMDLs if those actions are deemed necessary to achieve the waste load allocation and restore water quality. In accordance with EPA's November 2002 policy "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs," the waste load allocation itself will not become a permit requirement. The full text of EPA's policy can be viewed at http://www.epa.gov/npdes/pubs/final-wwtmdl.pdf

1.3.11 Other Local Government Requirements

Local governments have the option of applying more stringent requirements than those in this Manual. They are not required to base those more stringent requirements on a watershed/basin plan or their obligations under a TMDL. Project proponents should always check with the local governmental agency with jurisdiction to determine the stormwater requirements that apply to their project.

Jurisdictions may have interconnected sewer systems. Neighboring jurisdictions are encouraged to work together to establish consistent design criteria for stormwater facilities since the climatic, geologic, and hydrologic variation among neighboring jurisdictions is likely to be minimal. Where municipal separate storm sewer systems are interconnected between jurisdictions with different requirements, the downstream jurisdiction's requirements apply.

1.3.12 Local Government Role in Implementing State/Federal Permit Requirements and Programs

Due to their knowledge and understanding of local water bodies, relationships with local businesses, and proximity to project sites, local governments can play an important role in implementing and enforcing permits and programs such as construction and industrial stormwater permits and the Underground Injection Control program. Ecology is ultimately responsible for implementation of these and other permits and programs in Washington State, but recognizes that these programs can have only limited success without the support and assistance of local jurisdictions.

Specific suggested "Responsibilities of Local Jurisdictions" are highlighted in Chapter 2.1.2 "Redevelopment" and in each Core Element in Chapter 2.2 of this Manual. These sections are provided as guidance for jurisdictions that are planning programmatic activities to manage stormwater to protect local water quality. A few of these potential roles may be further defined through the UIC rule revision and the Phase II municipal stormwater permitting process for those jurisdictions. But in most cases, Ecology simply hopes to develop and maintain a cooperative working relationship with the local jurisdiction and focus limited resources on sites with the greatest potential to impact water quality.

1.4 Best Management Practices for Stormwater Management

1.4.1 Best Management Practices (BMPs)

The method by which the Manual mitigates the adverse impacts of development and redevelopment is through the application of Best Management Practices (BMPs). The BMPs included in this Manual have been approved by Ecology; as new technologies are evaluated and approved, additional BMPs will be published as updates to this Manual.

BMPs are defined as schedules of activities, prohibitions of practices, structural facilities, maintenance procedures, and/or managerial practices that when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State. The basic types of BMPs are (1) source control, (2) water quality treatment, and (3) flow control. BMPs that involve construction of engineered structures are often referred to as facilities in this Manual.

The primary purpose of using BMPs is to protect the beneficial uses of water resources (1) through prevention of contamination, (2) through the reduction of pollutant concentrations and loads, and/or (3) through management of discharge flow rates to prevent increased stream channel erosion. If it is found that beneficial uses are still threatened or impaired following the implementation of BMPs advocated in this Manual, then additional controls may be required.

1.4.2 Source Control BMPs

Source control BMPs prevent pollution or other adverse effects of stormwater from occurring. Most of these BMPs are common-sense "good housekeeping" measures and are targeted for various pollutant-generating activities and sources. Source control BMPs may be either operational or structural; examples include methods as varied as sweeping, using mulches and covers on disturbed soil, putting roofs over outside storage areas, and constructing berms around potential pollutant source areas to prevent both stormwater run-on and pollutant runoff. Core Element #3 "Source Control" in Chapter 2 defines the requirements for applying these BMPs; and Chapter 8 describes the procedures for implementing these BMPs.

It is generally more cost effective to use source controls to prevent pollutants from entering runoff than to treat runoff to remove pollutants. However, since source controls cannot prevent all impacts some combination of measures will usually be needed. Project proponent should try to design and place structures at the site so that stormwater does not come into contact with pollutants, reducing the requirement for treatment.

1.4.3 Water Quality Treatment BMPs

Water quality treatment BMPs include facilities that remove pollutants from stormwater by filtration, biological uptake, adsorption, and/or gravity settling of particulate pollutants. The need for a project to provide runoff treatment facilities depends on (1) the type and amount of pollutants expected to be generated by the completed project and (2) the vulnerability of the receiving waters to the pollutants of concern. A combination of BMPs may be required to protect the receiving waters.

Water quality treatment BMPs can accomplish significant levels of pollutant load reductions if properly selected, designed, operated, and maintained. Some water quality treatment BMPs are targeted for removal of a specific type of pollutant; others are effective at removing several classes of pollutants. Some BMPs may be appropriate only for certain climates or under other conditions.

It is not generally practical to treat 100 percent of the annual stormwater runoff volume generated by a project site. Some of the design specifications for water quality treatment BMPs in this Manual are established such that the BMPs are presumed to treat at least 90 percent of the total average annual runoff volume; this amount is considered to be a reasonable goal for capturing as many contaminants as practicable. Other BMP design specifications are based on treating the “first flush” of each storm event: stormwater produced by first rainstorm following a dry period during which pollutants have accumulated on impervious surfaces is commonly believed to carry a majority of the pollutants in urban runoff.

For groundwater, the potential of filtration through the vadose zone to remove the solid phase portion of the total concentration may result in concentrations meeting state groundwater quality standards (WAC 173-200). However, relying on the vadose zone to remove pollutants may result in contaminated soil, especially for sites with more than moderate to high pollutant loadings. See Chapter 5.6 for the background and rationale for allowing use of the vadose zone to provide treatment in certain cases.

Core Element #5 “Runoff Treatment” in Chapter 2 defines the requirements for applying these BMPs; and Chapters 4 and 5 describe the design criteria and procedures for implementing these BMPs.

1.4.4 Flow Control BMPs

Flow control BMPs may control the rate, frequency, and/or flow duration of stormwater surface runoff. Excess stormwater runoff volumes are generally managed by use of infiltration, evaporation, or detention facilities. On-site infiltration is the preferred means of disposing of stormwater runoff but is feasible only where more porous soils are available and the water table is not within 5 to 15 feet of the land surface, depending on local conditions. With the lower amounts of runoff in the arid and semi-arid climate of eastern Washington, infiltration is feasible in many areas of new development.

For projects with discharges to surface waters, detention ponds are designed and operated to meet established flow control requirements. The concept of detention is to collect runoff from a developed area and release it at a slower rate than it enters the collection system. The reduced release rate requires temporary storage of the excess amounts in a pond with release occurring over a few hours or days. The volume of storage needed is dependent on (1) the size of the drainage area; (2) the extent of disturbance of the natural vegetation, topography, and soils and creation of effective impervious surfaces – surfaces that drain to a stormwater collection system; and (3) how rapidly the water is allowed to leave the detention pond, i.e., the target release rates.

Historic flow control measures have focused on controlling runoff by matching the existing and proposed development peak flow rates for the certain recurrence intervals. This level of control does not adequately address the increased duration at which those high flows occur because the volume of water from the proposed development condition is increased as compared to the pre-developed and(or) existing conditions. The approach of only matching the peak flow rates fails to protect stream habitats from increased erosional energy.

To protect stream channels from increased erosion, it is necessary to control the durations over which a stream channel experiences geomorphically significant flows such that the energy imparted to the stream channel does not increase significantly. Discharges to lakes are controlled primarily to protect the outlet stream. Geomorphically significant flows are those that are capable of moving sediments; for most streams, these flows are within the 1.5- to 2-year range of recurrence intervals. If the pre-developed or existing condition 2-year peak runoff rate is met for the entire 2-year proposed development condition runoff volume, the stream experiences that flow rate for the longer period necessary to release the increased volume of runoff in the proposed development condition. In the absence of a continuous runoff model, a full duration standard cannot be achieved. A partial duration standard can be implemented by releasing the proposed development condition 2-year runoff volume at half of the pre-developed or existing condition 2-year peak flow rate, thus reducing the total erosional energy to somewhat nearer to that of the pre-developed or existing condition. This target will translate into lower release rates and larger detention ponds. The size of the facility can be reduced by reducing the extent to which a site is disturbed.

For discharges to wetlands, the objective of flow control is to not alter the natural hydroperiod. This means that flows from a development should be controlled such that the wetland is within certain elevations at different times of the year and that short-term elevation changes are within prescribed limits. If the amount of surface water runoff draining to a wetland is increased because of land conversion from native vegetation to impervious areas, it may be necessary to bypass some water around the wetland in the wet season. (Bypassed stormwater must still meet flow control and treatment requirements applicable to the receiving water.) If however, the wetland was fed by local ground water elevations during the dry season, the impervious surface additions and the bypassing practice may cause variations from the dry season elevations. Accurate estimates of what should be done to maintain the natural hydroperiod require data collection prior to the development activity and the use of a continuous runoff model.

Core Element #6 “Flow Control” in Chapter 2 defines the requirements for applying these BMPs; and Chapters 4 and 6 describe the design criteria and procedures for implementing these BMPs.

1.4.5 New and Emerging BMPs

Ecology encourages the development and implementation of new approaches to managing and treating stormwater. This Manual is intended to be a living document, and project proponents should check Ecology's website for additional BMPs that have been approved since the publication of this Manual. More information is provided in Chapter 5.12 about the new statewide protocol for testing new and emerging stormwater management technologies.

1.5 How to Apply this Manual

The users of this Manual will be engineers, planners, private industry, environmental scientists, plan reviewers, and inspectors at the local, state, and federal government levels. Ecology may approve other stormwater management manuals developed by local jurisdictions, the Washington State Department of Transportation, or other entities as being equivalent to this Manual. Local government officials may adopt and apply the requirements of this Manual directly or adopt and apply the requirements of an equivalent manual (see Section 1.5.2, Alternative Technical Manuals below). Local government staff may use this Manual or an equivalent manual as a reference for reviewing stormwater site plans; checking source control, runoff treatment, and flow control facility designs; and for providing technical advice in general. Private industry may use the Manual for information on how to develop and implement stormwater site plans and as a reference for technical specifications of Best Management Practices (BMPs).

The Manual itself has no independent regulatory authority. The Core Elements and technical guidance in the Manual become required only through:

- Ordinances and rules established by local governments; and
- Permits and other authorizations issued by local, state, and federal authorities.

Local jurisdictions may adopt and apply the Core Elements, thresholds, definitions, BMP selection processes, and BMP design criteria of this Manual or an equivalent manual. Staff at local governments and agencies with permitting jurisdiction may use this Manual in reviewing stormwater site plans, checking BMP designs, and providing technical advice to project proponents.

Federal, state, and local permits may refer to this Manual or the BMPs contained in this Manual. In those cases, affected permit-holders or applicants should use this Manual for specific guidance on how to comply with permit conditions.

Project proponents should start by reading Chapter 2 of this Manual. Chapter 2 explains the requirements of the Core Elements and defines how the Core Elements should be applied to individual projects and to particular levels of development.

For several of the Core Elements, thresholds are identified. These are the levels or conditions (e.g., project size or proposed land use) at or for which an action becomes required for that project. The thresholds presented in Chapter 2 are *technical thresholds*. However, *regulatory thresholds* may be established in ordinances, rules, permits or other authorizations; these thresholds are not included in this Manual but may modify certain thresholds that need to be met for a given project to comply with one or more Core Elements.

1.5.1 Stormwater Technical Manual

This Manual serves as a single technical stormwater manual for eastern Washington. It provides uniform stormwater management standards and is a central repository for BMPs. Ecology will maintain the region's technical stormwater manual for new development and redevelopment and will update, revise, and republish this Manual as appropriate.

1.5.2 Alternative Technical Manuals

Cities, counties, and other agencies may choose to develop alternative technical manuals. Those agencies and jurisdictions subject to state and federal regulatory programs that refer to this Manual may be directed to submit their manuals to Ecology. The submittal must include an outline of significant differences between the manuals and demonstrate how the alternative manual is substantively equivalent to this Manual. Ecology will work with jurisdictions to ensure that alternative manuals meet the regulatory objectives for which this Manual is being required (e.g., protection of water quality). Where Ecology is uncertain that a local jurisdiction or agency requirement provides sufficient protection, it may provisionally approve the requirement. The provisions would require the local jurisdiction or agency to implement an approved monitoring effort to assess the performance of the local requirement. Jurisdictions and agencies choosing to develop alternative manuals may be directed to adopt this Manual in the interim.

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Chapter 2 - Core Elements for New Development and Redevelopment

2.1 Introduction

This chapter identifies and defines the eight Core Elements of stormwater management. These Core Elements are applicable to new development and redevelopment projects in eastern Washington. Not all Core Elements apply to every project, and depending on the type and size of a project, different combinations of the eight Core Elements will apply. See Chapter 1.3 of this Manual for the regulatory framework and conditions under which the Manual may be required for various projects; also see Chapter 1.1.3 for a description of using a demonstrative approach to protecting water quality in lieu of following the Manual. Best Management Practices (BMPs) for implementing the Core Elements are described in Chapters 5 through 8 of this Manual. Specific project exemptions are listed in sections 2.1.3 and 2.1.4 below. See the Glossary for definitions of some of the words and phrases used in this section.

The Core Elements are:

1. **Preparation of a Stormwater Site Plan**
2. **Construction Stormwater Pollution Prevention**
3. **Source Control of Pollution**
4. **Preservation of Natural Drainage Systems**
5. **Runoff Treatment**
6. **Flow Control**
7. **Operation and Maintenance**
8. **Local Requirements**

The purpose and applicability of each of these Core Elements is summarized in Table 2.1.1 and described in detail in section 2.2. Project proponents need to be familiar with the contents of this Chapter in order to determine which Core Elements apply to a given project.

Both **Guidelines** and **Supplemental Guidelines** are provided under the Redevelopment definition and under the Core Elements. The guidelines must be followed in order for a project to comply with the stormwater management provisions set forth in this Manual. Supplemental guidelines are optional and are included for consideration under special circumstances; these guidelines may be required in certain jurisdictions.

The sections on **Responsibilities of Local Jurisdictions** are provided as guidance for jurisdictions that are planning programmatic activities to manage stormwater to protect surface and groundwater quality.

Table 2.1.1 – Purpose and applicability of the Core Elements

Core Element		Purpose	Applicability
1	Preparation of a Stormwater Site Plan	To integrate stormwater management into project planning and design	Applicable to all sites; required if stipulated as part of a rule, ordinance, or permit issued by local, state or federal government
2	Construction Stormwater Pollution Prevention	To control erosion and prevent sediment and other pollutants from leaving the site	Applicable to all sites; required if stipulated as part of a rule, ordinance, or permit issued by local, state or federal government
3	Source Control of Pollution	To prevent stormwater from coming into contact with potential pollutants	Applicable to all sites; required if stipulated as part of a rule, ordinance, or permit issued by local, state or federal government
4	Preservation of Natural Drainage Systems	To maximize the extent to which stormwater discharge patterns, rates, and outfall locations remain the same after a development project	Applicable to all sites; required if stipulated as part of a rule, ordinance, or permit issued by local, state or federal government
5	Runoff Treatment	To protect water quality in the receiving water by reducing the loads and concentrations of pollutant in stormwater using biological, physical and chemical removal methods	Applicable only to sites that are determined to have sufficient pollutant-generating potential; required if stipulated as part of a rule, ordinance, or permit issued by local, state or federal government
6	Flow Control	To protect stream morphology and habitat by mitigating the impacts of increased storm runoff volumes and flow rates to streams	Applicable only to sites that discharge to non-exempt surface water bodies; required if stipulated as part of a rule, ordinance, or permit issued by local, state or federal government
7	Operation and Maintenance	To prevent failure of stormwater treatment facilities or improper discharges due to inadequate maintenance or improper operation	Applicable to all sites with runoff treatment or flow control facilities; required if stipulated as part of a rule, ordinance, or permit issued by local, state or federal government
8	Local Requirements	To provide for additional conditions or measures needed to protect local water bodies or for other reasons	Applicable to and required for all sites where such measures have been established by local ordinance or rule

2.1.1 New Development

New development is the conversion of previously undeveloped or pervious surfaces to impervious surfaces and managed landscape areas not specifically exempt below in section 2.1.3 or 2.1.4. See Chapter 1 for the regulatory framework under which a project may be directed to use this Manual or an approved equivalent.

All new development projects must comply with:
Core Element #1 Preparation of a Stormwater Site Plan,
Core Element #2 Construction Stormwater Pollution Prevention,
Core Element #3 Source Control of Pollution,
Core Element #4 Preservation of Natural Drainage Systems, and
Core Element #8 Local Requirements.

When the thresholds for Core Element #5 Runoff Treatment are met (see section 2.2.5), the following Core Elements also apply:
Core Element #5 Runoff Treatment, and
Core Element #7 Operation and Maintenance.

When the thresholds for Core Element #6 Flow Control are met (see section 2.2.6), the following Core Elements also apply:
Core Element #6 Flow Control, and
Core Element #7 Operation and Maintenance.

Projects that add new lanes on an existing roadway or otherwise expand the pavement edge are included in the definition of new development because they create new impervious surfaces. These projects are subject to the thresholds and requirements set forth in this Manual or adopted by a local jurisdiction or agency.

2.1.2 Redevelopment

Redevelopment is defined as the replacement or improvement of impervious surfaces on a developed site. Impervious surface replacements defined as exempt activities in section 2.1.3 and other projects identified in section 2.1.4 have reduced requirements. The project proponent must identify what Core Elements apply to all of the new and replaced impervious surfaces created by the project. All new impervious surfaces added during a redevelopment project are subject to the Core Elements identified in 2.1.1 above. The following sections apply to the impervious surfaces altered by a redevelopment project.

Objective

The long-term goal of the redevelopment standard is to reduce stormwater pollution from existing developed sites, especially when a water quality problem has been identified or the site is being improved to accommodate a use with a greater potential to contribute pollution to the receiving waters. More stringent redevelopment thresholds and requirements may be identified through a water cleanup plan such as a Total Maximum Daily Load (TMDL) study and allocation or another basin planning process.

To encourage redevelopment projects, replaced or improved surfaces are not required to meet new stormwater standards unless the use or area thresholds identified in the Guidelines section below are met or exceeded for the redevelopment project scope. As long as the replaced or improved surfaces have similar pollution-generating potential, the amount of pollutants discharged should not be significantly different. However, following a rationale consistent with other utility standards, some redevelopment projects are required to meet current stormwater standards. (When a structure or a property undergoes significant remodeling, local jurisdictions may require the site to meet new building code requirements such as onsite sewage disposal systems, wheelchair access provisions and(or) fire systems.) Upgrading stormwater infrastructure is generally more economical when included as part of a redevelopment project than when undertaken as a separate effort.

See Chapter 1 for the regulatory framework under which a redevelopment project may be directed to use this Manual or an approved equivalent.

Impervious surfaces created by development are classified as either non-pollutant-generating (NPGIS) or pollutant-generating (PGIS) as described in detail in section 2.2.5 Core Element #5 Definitions. The majority of the impervious surfaces in a watershed are either NPGIS or PGIS with low pollutant loadings. The PGIS with low pollutant loadings may contribute a substantial portion of the cumulative stormwater pollutant load received by a water body. But in the absence of a documented water quality problem, the standard for applying runoff treatment to redevelopment projects in eastern Washington applies primarily to sites where pollutant concentrations in runoff are expected to exceed water quality standards. Therefore, replaced impervious surfaces with low pollutant loadings are not generally subject to runoff treatment requirements in eastern Washington; but treatment is required for redeveloped surfaces (PGIS) with medium or high pollutant loadings (see guidelines below).

Guidelines

When the following conditions are met, the identified Core Elements (detailed in sections 2.2.1 through 2.2.8) apply to replaced impervious surfaces. For projects that are implemented in incremental stages, the redevelopment threshold applies to the total amount of impervious surfaces replaced at full build-out; the new development thresholds apply to the total amount of impervious surfaces added at full build-out. To maintain their integrity and function, stormwater treatment facilities must be sized for the entire flow that is directed to them.

Where replacement of 5,000 square feet or more of existing PGIS occurs:

- **Core Elements 1, 2, 3, 4, 7, and 8** shall apply to the portion of the site where any impervious surfaces are replaced (includes both PGIS and NPGIS areas).
- **Core Elements 2 and 3** shall be applied to the entire site that is affected by the project activities.
- In addition to the above requirements, **Core Element 5** shall be applied to the replaced PGIS area at the site if any of the following conditions exist. Unless otherwise noted, the project is only required to provide basic runoff treatment to remove solids.
    - The project takes place at an industrial site as defined by EPA (40 CFR 122.26(b)(14)) with outdoor handling, processing, storage, or transfer of solid raw materials or finished products. Additional treatment to remove metals is required for sites that are subject to benchmark monitoring requirements for metals.
    - The project takes place at a commercial site with outdoor storage or transfer of solid raw materials or treated wood products.
    - A need for additional stormwater control measures has been identified through a TMDL or other water cleanup plan or other planning process. (Local jurisdictions are cautioned that they may have difficulty meeting TMDL waste load allocations if they wait until corrective actions are required by a TMDL. See Supplemental Guidelines below.)
    - The project takes place at a "high-use site" as defined in section 2.2.5 Core Element #5 Definitions. Additional treatment must be provided to remove oil at high-use sites.
    - The project takes place in an area subject to vehicular traffic under any of the following conditions. Preservation/maintenance projects and some improvement and safety enhancement projects that do not increase motorized vehicular capacities are exempt from the Core Elements as defined in section 2.1.3 or partially exempt as defined in section 2.1.4. *See the definition of average daily traffic and trip ends in Core Element 5 (Chapter 2.2.5).*
        a) The project improves a soft shoulder to a curb and gutter roadway with an average daily traffic volume of 7,500 or more vehicles. (See section 2.1.4 for partial exemptions for other safety improvement projects.)
        b) The project replaces and(or) improves the surface of a parking area where the projected number of trip ends exceeds 40 per 1,000 square feet of building area or 100 total trip ends per day. Additional treatment to remove both oil and metals is required

if the projected number of trip ends exceeds 100 per 1,000 square feet of building area or 300 total trip ends per day.

c) The project replaces and(or) improves the surface of an urban road where the projected average daily traffic volume is 7,500 or more vehicles per day. Additional treatment to remove both oil and metals is required if the average daily traffic volume is greater than 30,000 vehicles per day.

d) The project replaces and(or) improves the surface of a rural road, freeway, or highway with limited access control where the projected average daily traffic volume is 15,000 or more vehicles per day. Additional treatment to remove both oil and metals is required if the average daily traffic volume is greater than 30,000 vehicles per day. (A *freeway* is defined as a multilane, arterial highway with full access control.)

e) The project affects the area within 500 feet of a controlled intersection on a limited access control highway with projected average daily traffic volume of 7,500 or more vehicles per day. Only this area must be treated.

- In addition to the above requirements, **Core Element 6** shall be applied to all of the replaced impervious surfaces at the site (includes both PGIS and NPGIS areas) if required by the state, federal, or local jurisdiction based on flooding studies or habitat assessments.

Local Retrofit Programs:

If the local jurisdiction has an equivalent or more stringent retrofit program in place, then those requirements may replace these conditions. The program must meet the intent of the requirements above and may need to be approved by Ecology. The requirements must be at least as stringent as the thresholds above, meaning that the number and types of projects regulated by the local requirements is the same or greater. Local jurisdictions can select from various bases for identifying projects that must retrofit the replaced impervious surfaces on the project site. Those can include:

- Exceeding 50% of the assessed value of the existing improvements;
- Exceeding 50% of the replacement value of the existing site;
- Exceeding a certain dollar value of improvements;
- Exceeding a certain ratio of the new impervious surfaces to the total of replaced plus new impervious surfaces; or exceeding an established threshold of added or replaced surfaces (e.g., the project adds 10,000 square feet or more of new impervious surfaces or replaces 20,000 square feet of impervious surfaces);

- There is a change in the use of the site to a use with greater potential to contaminate stormwater.

The local jurisdiction may allow the Core Elements to be met for an area with equivalent flow and pollution characteristics within the same site. For public road projects, the equivalent area does not have to be within the project limits, but must drain to the same water body segment and be located upstream from a confluence with another water body downstream from the project site.

A local jurisdiction may provide exemptions or institute a maximum retrofitting cost provision for redevelopment projects from compliance with Core Elements for treatment, flow control, and wetlands protection as applied to the replaced impervious surfaces if the local jurisdiction has adopted a plan and a schedule that fulfills those requirements in regional facilities.

Supplemental Guidelines

Local jurisdictions may institute a stop-loss provision on the application of stormwater requirements to replaced impervious surfaces. A stop-loss provision is an upper limit on the extent to which a requirement is applied. For instance, there could be a maximum percentage of the estimated total project costs that are dedicated to meeting stormwater requirements. A project would not have to incur additional stormwater costs above that maximum though the standard redevelopment requirements will not be fully achieved. Allowances may also be made for sites that would, by imposing the treatment requirement, become non-conforming to other requirements that apply to the site. Every effort should still be made to find creative ways to meet the intent of the Core Elements. The allowance for a stop-loss provision pertains to the extent that treatment, flow control and wetlands protection requirements are imposed on replaced impervious surfaces. It does not apply to meeting stormwater requirements for new impervious surfaces.

For redevelopment projects that discharge into the municipal storm sewer system, local jurisdictions may also establish criteria for allowing payment of a fee-in-lieu of constructing water quality or flow control facilities. At a minimum, the fee should be the equivalent of an engineering estimate of the cost of meeting all applicable stormwater requirements for the project. The local jurisdiction should use such funds for the implementation of stormwater control projects that would have similar benefits to the same receiving water as if the project had constructed its required improvements. The stormwater control project could be a regional facility that includes service to the redevelopment site, or a facility serving other public or private lands tributary to the same receiving water. Expenditure of such funds is subject to other state statutory requirements.

Ecology cautions local jurisdictions about the potential long-term consequences of allowing a fee-in-lieu of stormwater facilities. Sites that are allowed to pay a fee continue without stormwater controls. If it is determined, through future basin planning for instance, that controls on such sites are necessary to achieve water quality goals or legal requirements, the public may bear the costs for providing those controls.

Local jurisdictions may require treatment facilities for redevelopment projects that discharge to a receiving water that has a documented water quality problem. This provision should focus on water quality problems for metals, oil and grease, bacteria, sediment, suspended solids, phosphorus, or any other water quality problem to which stormwater is considered a contributor.

Sites with 100% existing building coverage that are currently connected to a municipally-owned storm sewer or combined sewer must be evaluated on a case-by-case basis to continue to be connected without treatment; additional local requirements such as flow restrictors may also be required.

Responsibilities of Local Jurisdictions

As part of the routine project approval and permitting process, local jurisdictions should review redevelopment project plans for intent and completeness in meeting the redevelopment guidelines. Where space is limited, staff may assist project proponents in modifying BMPs and(or) finding creative ways to meet the intent of the Core Elements. Local jurisdictions should begin planning regional treatment facilities in areas where meeting the on-site treatment objectives for individual redevelopment projects will be challenging.

2.1.3 Exemptions

The following practices are exempted from the Core Elements:

Forest Practices
Forest practices regulated under Title 222 WAC are exempt from the provisions of the Core Elements. Conversions of forest lands to other uses are not exempt.

Commercial Agriculture
Commercial agriculture practices involving working the land for production are generally exempt. However, the construction of impervious surfaces is not exempt.

Road and Parking Area Preservation/Maintenance
The following road and parking area maintenance practices are exempt (see also section 2.1.4 Partial Exemptions below):

- Pothole and square cut patching;
- Crack sealing;
- Resurfacing with in-kind material without expanding the road prism;

- Overlaying existing asphalt or concrete pavement with bituminous surface treatment (BST or "chip seal"), asphalt or concrete without expanding the area of coverage;
- Shoulder grading;
- Reshaping/regrading drainage systems; and
- Vegetation maintenance.

2.1.4 Partial Exemptions

The following practices are generally exempted from all of the Core Elements except for Core Element #1 Preparation of a Stormwater Site Plan and Core Element #2 Construction Stormwater Pollution Prevention:

Underground Utility Projects
Underground utility projects that replace the ground surface with in-kind material or materials with similar runoff characteristics are subject only to Core Element #1 Preparation of a Stormwater Site Plan and Core Element #2 Construction Stormwater Pollution Prevention.

Road and Parking Area Preservation/Maintenance
A preservation or maintenance project is defined as preserving/protecting infrastructure by rehabilitating or replacing existing structures to maintain operational and structural integrity, and for the safe and efficient operation of the facility. Maintenance projects do not increase the traffic capacity of a roadway or parking area. The following practices are subject only to Core Element #1 Preparation of a Stormwater Site Plan and Core Element #2 Construction Stormwater Pollution Prevention:

- Removing and replacing a concrete or asphalt roadway to base course or subgrade or lower without expanding or improving the impervious surfaces.
- Repairing the roadway base or subgrade.
- Overlaying existing gravel with bituminous surface treatment (BST or "chip seal") or asphalt or concrete without expanding the area of coverage, or overlaying BST with asphalt, without expanding the area of coverage. <u>For this type of project, partial exemption applies **only** under the following conditions</u>:
    - For roads, these practices are exempt from additional Core Elements **only** if the traffic surface will be subject to an average daily traffic volume of less than 7,500 on an urban road or an average daily traffic volume of less than 15,000 vehicles on a rural road, freeway, or limited access control highway. If these thresholds are exceeded, refer to the Redevelopment Guidelines in section 2.1.2 to determine which Core Elements apply.
    - For parking areas, these practices are exempt from additional Core Elements **only** if the traffic surface will be subject to less than 40 trip ends per 1,000 square feet of building area or 100 total trip

ends. If these thresholds are exceeded, refer to the Redevelopment Guidelines in section 2.1.2 to determine which Core Elements apply.

Safety Improvement Projects
Projects to improve motorized and(or) non-motorized user safety that do not enhance the traffic capacity of a roadway are subject only to Core Element #1 Preparation of a Stormwater Site Plan and Core Element #2 Construction Stormwater Pollution Prevention except as specified under sub-item (a) under conditions for applying Core Element #5 Runoff Treatment in section 2.1.2 Redevelopment Guidelines. Certain safety improvement projects such as sidewalks, bike lanes, bus pullouts and other transit improvements must be evaluated on a case-by-case basis to determine whether additional Core Elements apply. A safety project that enhances the traffic carrying capacity of a roadway is <u>not</u> exempt from other Core Elements.

2.1.5 Local Exceptions/Variances

<u>Guidelines</u>

Exceptions to the Core Elements may be granted prior to permit approval and construction. The local jurisdiction may grant an exception following an application for an exception with legal public notice per the local jurisdiction's guidance and requirements for exceptions and variances. The administrator's decision should include a written finding of fact that documents the following:

- There are special physical circumstances or conditions affecting the property such that would prohibit the strict application of these provisions; and
- Every effort has been made to find alternative ways to meet the objectives of the Core Elements; and
- The granting of the exception or variance will not be detrimental to the public health and welfare, nor injurious to other properties in the vicinity and/or downstream, and to the quality of waters of the state; and
- The exception is the least possible exception that could be granted to comply with the intent of the Core Elements.

If the local jurisdiction chooses to allow jurisdiction-wide exceptions or variances to the requirements of the Manual, those exceptions must be approved by Ecology or other agency exercising its permitting authority. Project-specific design deviations based on site-specific conditions generally do not require approval of the permitting authority and are left to the discretion of the local jurisdiction.

Supplemental Guidelines

The adjustment and exception provisions are an important element of the plan review and enforcement programs. They are intended to maintain a necessary flexible working relationship between local officials and applicants. Local jurisdictions should consider these requests judiciously, keeping in mind both the need of the applicant to maximize cost-effectiveness and the need to protect off-site properties and resources from damage.

2.2 Core Elements

This section describes the eight Core Elements for stormwater management at development and redevelopment sites in eastern Washington. Chapters 5 through 8 of this Manual contain Best Management Practices (BMPs) to choose from in implementing these Core Elements for each project.

The requirements of these Core Elements do not excuse any discharge from the obligation to apply whatever technology is necessary to comply with state water quality standards, Chapter 173-201A WAC, or state groundwater standards, Chapter 173-200 WAC. Additional treatment requirements to meet those standards may be required by federal, state, or local jurisdictions.

This Manual is intended to assist projects discharging to surface water and projects with discharges to groundwater via Underground Injection Control (UIC) Facilities in complying with regulatory requirements to protect water quality. Nearly all of this section applies to projects with discharges to surface water, and most of it also applies to projects with discharges to groundwater. Each Core Element includes a section identifying the applicability of that Core Element to projects disposing of stormwater runoff using UIC facilities in order to clarify how the Core Element might be applied differently for projects discharging to surface and groundwaters. Some Core Elements also include a section on applicability to wetlands where special considerations are needed for those discharges.

2.2.1 Core Element #1
Preparation of a Stormwater Site Plan

Objective

Stormwater management is most successful when integrated into project planning and design. Projects are expected to demonstrate compliance with the applicable Core Elements through preparation of a Stormwater Site Plan.

Guidelines

All projects that are subject to Core Elements #2, #3, #4, #5, #6 or #8 are expected to complete a Stormwater Site Plan (SSP). When required, Stormwater Site Plans shall be prepared in accordance with Chapter 3 of this Manual.

Projects proposed by departments and agencies within the local jurisdiction must comply with this requirement. The local jurisdiction shall determine the process for ensuring proper project review, inspection, and compliance by its own departments and agencies.

Applicability to UIC Facilities

This Core Element applies to projects with drywells and other UIC rule-authorized subsurface infiltration systems when Core Elements #2, #3, #4, #5, #6 or #8 are required.

Supplemental Guidelines

A simplified SSP may be developed by the local jurisdiction and made available for use by proponents of small projects.

Responsibilities of Local Jurisdictions

As part of the routine project approval and permitting process, local jurisdictions should review SSPs for completeness and adequacy in fulfilling the objectives of the Core Elements. Plan review staff should be trained in the application of this Manual or the approved local equivalent.

2.2.2 Core Element #2 Construction Stormwater Pollution Prevention

Objective

Runoff from project sites during the construction phase can contribute quantities of sediment and other contaminants sufficient to result in water quality violations. Sediment-laden runoff can enter newly constructed drywells, reducing their infiltration capacity and lifetime of operation or increasing maintenance costs.

Controlling erosion and preventing sediment and other pollutants from leaving the project site during the construction phase is achievable through implementation of selected Best Management Practices (BMPs) that are appropriate both to the site and to the season during which construction activities take place. The Construction Stormwater Pollution Prevention Plan (SWPPP) identifies project-specific guidance for preventing pollution resulting from erosion and sediment runoff during the construction phase. A well-written SWPPP provides guidance that is neither over- nor under-protective for the project site. The Construction SWPPP should include seasonally-appropriate guidance and anticipate adjustments that may be necessary in the event of delays in the construction schedule.

Guidelines

When this Core Element is required, Core Element #1 Preparation of a Stormwater Site Plan is also required.

Construction SWPPP Elements

All projects are responsible for preventing erosion and discharge of sediment into surface waters and must consider each of the twelve elements of pollution prevention in order to determine which controls are appropriate for the project site. Chapter 7 of this Manual identifies and describes appropriate Best Management Practices (BMPs) for each of these elements.

The twelve Construction SWPPP elements are listed below. See Chapter 7 for a description of each of these elements and suggested BMPs for each element.

1. Mark Clearing Limits
2. Establish Construction Access
3. Control Flow Rates
4. Install Sediment Controls
5. Stabilize Soils
6. Protect Slopes
7. Protect Drain Inlets
8. Stabilize Channels and Outlets
9. Control Pollutants
10. Control De-Watering
11. Maintain BMPs
12. Manage the Project

If a Construction SWPPP is found to be inadequate with respect to applicable erosion and sediment control requirements (i.e., sediment-laden water is leaving the site), then the local jurisdiction shall require that other BMPs be implemented as appropriate.

Maintaining an Updated SWPPP

The Construction SWPPP must be maintained on the construction site for reference and use by project personnel. The SWPPP, including the site map, must be amended whenever there is a change in design, construction, operation, or maintenance at the construction site that has or could have a significant effect on the discharge of pollutants to surface or ground water that has not been previously addressed in the SWPPP. The SWPPP must be amended if during inspections or investigations by site staff, or by the jurisdiction, it is determined that the SWPPP is ineffective in eliminating or significantly minimizing pollutants in stormwater discharges from the construction site. Based on the results of an inspection, the SWPPP must be modified as necessary to include additional or modified BMPs designed to correct problems identified. Revisions to the SWPPP must be completed within seven calendar days following the inspection. Implementation of these additional or modified BMPs must be accomplished before the next storm event whenever practicable. Where implementation before the next storm event is impracticable, the situation must be documented in the SWPPP and alternative BMPs must be implemented as soon as possible.

Applicability to UIC Facilities

This Core Element is required for all projects with drywells and other UIC rule-authorized subsurface infiltration systems to protect and ensure the proper long-term function of the UIC facility. Preventing sediment from entering the facility may be all that is necessary to achieve this objective. Source control during construction (SWPPP element #9) is also required to prevent contamination of groundwater by fuel or other potential pollutants.

Supplemental Guidelines

The local jurisdiction may allow development of generic Construction SWPPPs that apply to commonly conducted projects such as public road activities.

Responsibilities of Local Jurisdictions

Local jurisdictions should review SWPPPs for completeness and adequacy in meeting the objectives of this Core Element. Staff inspecting projects during construction should be trained in assessing the application of erosion and sediment control BMPs; if problems are identified, staff should review the SWPPPs on-site and discuss appropriate modifications with operators.

2.2.3 Core Element #3 Source Control of Pollution

Objective

The intent of Source Control Best Management Practices (BMPs) is to prevent pollutants from coming into contact with stormwater. Source control BMPs are a cost-effective means of reducing pollutant loading and concentrations in stormwater and should be a first consideration in all projects.

Guidelines

Following construction, projects shall apply all known, available and reasonable source control BMPs. Source control BMPs shall be selected, designed, and maintained according to this Manual.

Considering opportunities for structural separation of surfaces exposed to pollutants and other source control alternatives during the project design stage may result in eliminating or reducing the size of facilities required under Core Element #5 Runoff Treatment.

Applicability to Wetlands

This Core Element is required for all projects with discharges to wetlands. Operational and source control BMPs may not be sufficient to protect wetlands from salts and other chemical anti-icers and deicers that can accumulate and impact the biological functions of a wetland. Separation and routing of runoff to an alternate discharge location may be necessary to protect the wetland from runoff from road and other surfaces subject to such chemical use.

Applicability to UIC Facilities

This Core Element is required for all projects with discharges to drywells and other UIC rule-authorized subsurface infiltration systems.

Supplemental Guidelines

A basin plan adopted and implemented by a local jurisdiction or a Total Maximum Daily Load (TMDL, also known as a Water Cleanup Plan) may be used to develop more stringent source control requirements that are tailored to a specific basin.

Source Control BMPs include Operational BMPs and Structural Source Control BMPs. See Chapter 8 for design details of these BMPs. For construction sites, see Chapter 7.

Responsibilities of Local Jurisdictions

During plan review, local jurisdictions should evaluate whether selected source BMPs will meet the objectives of this Core Element. Staff conducting inspections of commercial and industrial facilities should be trained in assessing the proper selection and implementation of source control BMPs; staff should review pollution prevention and spill control plans and discuss appropriate modifications with operators if a problem is identified.

2.2.4 Core Element #4 Preservation of Natural Drainage Systems

Objective

Natural drainage patterns should be maintained and discharges from the project site should occur at the natural location to the maximum extent practicable. Preservation of natural drainage systems provides multiple benefits for stormwater management. Creating new drainage patterns results in more site disturbance and more potential for erosion and sedimentation during and after construction. Creating new discharge points can create significant stream channel erosion problems as the receiving water body typically must adjust to the new flows. Diversions can cause greater impacts than would otherwise occur by discharging runoff at the natural location. Wetlands can be severely degraded by discharges from urban development due to pollutants in the runoff and also due to disruption of the natural hydrology (especially changes in water levels and the duration of inundations) of the wetland system.

Guidelines

To the maximum extent practicable, stormwater should be discharged in the same manner, at the same location, and at the same flow rate and volume as under the conditions that existed prior to development. Because some change in natural flow patterns is unavoidable following development, the preferred options for discharge of excess stormwater are, in order of preference to maintain natural drainage systems:

1. Maintain dispersed sheet flow to match natural conditions.
2. Infiltrate on-site.
3. Infiltrate off-site.
4. Discharge to existing ditch networks, canals, or other dispersal methods that allow for potential groundwater recharge.
5. Discharge to wetlands, if allowed.
6. Discharge to existing private or municipally-owned stormwater systems, if allowed.
7. Evaporate on-site or off-site.
8. Create a new outfall for discharge to surface waters.

This Core Element includes stormwater infiltration if that is the natural discharge method for the site. The designer shall investigate whether shallow groundwater, a sensitive aquifer, or other concerns will affect design choices for the project.

The manner by which runoff is discharged from the project site must not cause a significant adverse impact to downstream receiving waters and down-gradient properties. This should be addressed as part of the off-site analysis described in Appendix 3A.

All outfalls must address energy dissipation as necessary. A project proponent who believes that energy dissipation should not be required for a new outfall must provide justification in the project's stormwater site plan or drainage study report.

Runoff treatment or flow control may be required prior to any discharge according to the requirements of Core Elements #5 or #6.

Applicability to Wetlands

Discharge of stormwater to existing jurisdictional wetlands, either directly or via a conveyance system, should be avoided unless the wetland receives surface runoff from the existing site. If possible, only stormwater from landscape and roof areas should be discharged to wetlands. The discharge must comply with all applicable Core Elements to ensure that wetlands receive the same level of protection as any other waters of the state. See Core Elements #5 Runoff Treatment and #6 Flow Control for guidelines for evaluating whether an existing wetland may be used as a runoff treatment or flow control facility.

Applicability to UIC Facilities

This Core Element applies to all projects with discharges to drywells and other UIC rule-authorized subsurface infiltration systems.

Supplemental Guidelines

For projects with no identified discharge point, local jurisdictions may wish to adopt guidance for disposal of water collected for runoff treatment per the requirements of Core Element #5 Runoff Treatment. The guidance is intended to protect downstream properties from flooding as a result of post-construction concentrated runoff.

Where no conveyance system exists at the adjacent down-gradient property line, and the discharge was previously un-concentrated flow or significantly lower concentrated flow, then measures must be taken to prevent down-gradient impacts. Drainage easements from downstream property owners may be needed and should be obtained prior to approval of engineering plans.

Designs for outfall systems to protect against adverse impacts from concentrated runoff are included in Chapter 5.

Responsibilities of Local Jurisdictions

During plan review, local jurisdictions should consider whether the construction and stormwater management approaches meet the objectives of this Core Element. Local jurisdictions may also wish to provide project proponents with resources about appropriate low impact development (LID) techniques that can assist in meeting the objectives of this Core Element. For additional information about LID approaches and links to demonstration projects and research activities, see websites and links provided by the U.S. Environmental Protection Agency, Puget Sound Water Quality Action Team, or Ecology.

2.2.5 Core Element #5 Runoff Treatment

Objective

The purpose of runoff treatment is to reduce pollutant loads and concentrations in stormwater runoff using physical, biological, and chemical removal mechanisms to protect water quality so that beneficial uses of receiving waters are maintained and where applicable, restored. The most effective basic treatment BMPs remove about 80% of the total suspended solids contained in the runoff treated and a much smaller percentage of the dissolved pollutants. An analysis of the proposed land use at the project site is used to determine the pollutants of concern and the appropriate treatment method(s) to apply at the site. In some cases, additional treatment to remove oil, metals, and(or) phosphorus from stormwater runoff may be required to protect water quality.

The goal of this Core Element is to treat approximately 90% of the annual runoff generated by the pollutant-generating surfaces at a project site. The total quantity of pollutants removed from the stormwater will vary greatly from site to site based on precipitation patterns, land use, effectiveness of source control, and operation and maintenance of the treatment facilities. Proper operation and maintenance of runoff treatment BMPs may be more significant than the actual volume of runoff treated in protecting receiving waters over the long term.

When site conditions are appropriate, infiltration can potentially be the most effective BMP for runoff treatment. Given sufficient treatment capacity in the vadose zone below an Underground Injection Control (UIC) facility, such as a drywell, and the water table, no pre-treatment may be required for many of the pollutants of concern in stormwater. The criteria for determining whether pre-treatment is required for a given proposed land use and site location are explained in Chapter 5.6.

In some situations, full or partial dispersion may provide adequate treatment in addition to disposing of the excess runoff from a site. See the section on dispersion BMPs in Chapter 6. to determine whether one of these BMPs is a viable option for your project.

Definitions

Non-Pollutant Generating Impervious Surfaces (NPGIS)

NPGIS are considered to be insignificant or very low sources of pollutants in stormwater runoff. Roofs that are subject only to atmospheric deposition or normal heating, ventilation, and air conditioning vents are considered NPGIS. The following may also be considered NPGIS: paved bicycle pathways and pedestrian sidewalks that are separated from and not subject to drainage from roads for motor vehicles, fenced fire lanes, infrequently used maintenance access roads, and "in-slope" areas of roads. Sidewalks that are regularly treated with salt or other deicing chemicals are <u>not</u> considered NPGIS.

Pollutant Generating Impervious Surfaces (PGIS)

PGIS are considered to be significant sources of pollutants in stormwater runoff. Such surfaces include those that are subject to vehicular use, industrial activities, or storage of erodible or leachable materials that receive direct rainfall or run-on or blow-in of rainfall. Metal roofs are considered to be PGIS unless coated with an inert, non-leachable material. Roofs that are subject to venting of manufacturing, commercial or other indoor pollutants are also considered PGIS. A surface, whether paved or not, shall be considered PGIS if it is regularly used by motor vehicles. The following are considered regularly-used surfaces: roads, unvegetated road shoulders, bike lanes within the traveled lane of a roadway, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways.

Average Daily Traffic (ADT) and Trip Ends

The expected number of vehicles using a roadway or parking area is represented by the projected averge daily traffic volume considered in designing the roadway or by the projected trip end counts for the parking area associated with a proposed land use. ADT and trip end counts must be estimated using "Trip Generation" published by the Institute of Transportation Engineers or from a traffic study prepared by a professional engineer or transportation specialist with expertise in traffic volume estimation. ADT and trip end counts shall be made for the design year or expected life of the project (the intent is for treatment facilities to be added in the soonest period of disruptive construction). For project sites with seasonal or varied use, evaluate the highest period of expected traffic impacts.

Low ADT Roadways and Parking Areas

Urban roads with ADT fewer than 7,500 vehicles per day; rural roads and freeways with ADT less than 15,000 vehicles per day; and parking areas with less than 40 trip ends per 1,000 SF of gross building area or fewer than 100 total trip ends per day are considered to be low-use traffic areas. Examples include most residential parking, and employee-only parking areas for small office parks or other commercial buildings.

Moderate ADT Roadways and Parking Areas

Urban roads with ADT between 7,500 and 30,000 vehicles per day; rural roads and freeways with ADT between 15,000 and 30,000 vehicles per day; and parking areas with between 40 and 100 trip ends per 1,000 SF of gross building area or between 100 and 300 total trip ends per day are considered to be moderate-use traffic areas. Examples include visitor parking for small to medium commercial buildings with a limited number of daily customers.

High ADT Roadways and Parking Areas

Any road with ADT greater than 30,000 vehicles per day; and parking areas with more than 100 trip ends per 1,000 SF of gross building area or greater than 300 total trip ends are considered to be high-use traffic areas. Examples include commercial buildings with a frequent turnover of customers and other visitors.

Moderate-Use Sites

Moderate-use sites include moderate ADT roadways and parking areas (see definition above); primary access points for high-density residential apartments; most intersections controlled by traffic signals; and transit center bus stops. These sites are expected to generate sufficient concentrations of metals that additional runoff treatment is needed to protect water quality in non-exempt surface waters.

High-Use Sites

High-use sites generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil and(or) other petroleum products. High-use sites are land uses where sufficient quantities of free oil are likely to be present such that they can be effectively removed with special treatment. A high-use site is any one of the following:

- A road intersection with expected ADT of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway, excluding projects proposing primarily pedestrian or bicycle use improvements; or
- A commercial or industrial site with an expected trip end count equal to or greater than 100 vehicles per 1,000 square feet of gross building area (best professional judgment should be used in comparing this criterion with the following criterion); or

- A customer or visitor parking lot with an expected trip end count equal to or greater than 300 vehicles (best professional judgment should be used in comparing this criterion with the preceding criterion); or
- Commercial on-street parking areas on streets with an expected total ADT count equal to or greater than 7,500; or
- Fueling stations and facilities; or
- A commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including locations where heating fuel is routinely delivered to end users (heating fuel handling and storage facilities <u>are</u> subject to this definition); or
- A commercial or industrial site subject to use, storage, or maintenance of a fleet of 25 or more diesel vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.); or
- Maintenance and repair facilities for vehicles, aircraft, construction equipment, railroad equipment or industrial machinery and equipment; or
- Outdoor areas where hydraulic equipment is stored; or
- Log storage and sorting yards and other sites subject to frequent use of forklifts and(or) other hydraulic equipment; or
- Railroad yards.

<u>Exemptions</u>

Any of the exemptions below may be negated by requirements set forth in a Total Maximum Daily Load (TMDL) or other water cleanup plan.

Basic Treatment Exemptions

Non-pollutant generating impervious surface (NPGIS) areas are exempt from basic treatment requirements *unless* the runoff from these areas is not separated from the runoff generated from pollutant generating impervious (PGIS) surface areas. All runoff treatment facilities must be sized for the entire flow that is directed to them. Projects that meet the requirements for dispersal and infiltration (see Chapter 6, particularly BMP T5.30) and do not meet the requirements for oil treatment are exempt from basic treatment requirements. Discharges to surface water from projects with a total PGIS area <5,000 square feet are exempt from basic treatment requirements *unless* those areas are subject to the storage or handling of hazardous substances, materials or wastes as defined in 49 CFR 171.8, RCW 70.105.010, and(or) RCW 70.136.020. Discharges to UIC facilities may be exempt from basic treatment requirements if the vadose zone matrix between the bottom of the facility and the water table provides adequate treatment capacity (see Chapter 5.6).

Metals Treatment Exemptions

Discharges to non-fish-bearing streams are exempt from additional metals treatment requirements. Direct discharges to the main channels of the following rivers and direct discharges to the following lakes are exempt from metals treatment requirements: Banks Lake, Lake Chelan, Columbia

River, Grande Ronde River, Kettle River, Klickitat River, Methow River, Moses Lake, Potholes Reservoir, Naches River, Okanogan River, Pend Oreille River, Similkameen River, Snake River, Spokane River, Wenatchee River, and Yakima River. Subsurface discharges via rule-authorized Underground Injection Control (UIC) facilities (see Chapter 5.6) are also exempt from metals treatment requirements. Restricted residential and employee-only parking areas are exempt from metals treatment requirements unless subject to through traffic. Certain exemptions may exist for Category 4 wetlands (see "Use of Existing Wetlands to Provide Runoff Treatment" under Guidelines below.)

Oil Treatment Exemptions

No high-use sites or high ADT roads or parking areas are exempt from oil treatment requirements.

Guidelines

Treatment facilities shall be selected, designed, sized, constructed, operated and maintained in accordance with the guidance in Chapters 4 and 5 of this Manual. The flow chart at the beginning of Chapter 5 is intended to assist project proponents in selecting treatment BMPs.

All runoff treatment facilities must be sized for the applicable design storm(s) described in this section or according to alternative guidance as required by the local jurisdiction. In order to maintain the integrity and function of the treatment systems, stormwater runoff treatment facilities must be sized for the entire flow that is directed to them.

If it is possible for the project to meet treatment requirements by dispersal and infiltration (see Chapter 6.5, BMP F6.42), the runoff should not be collected and concentrated; otherwise flow control (Core Element #6) may be required.

When this Core Element is required, Core Element #7 Operation and Maintenance is also required.

Applicability to UIC Facilities

Discharge of untreated stormwater from PGIS to drywells and other UIC rule-authorized subsurface infiltration systems can be acceptable if the geologic matrix and depth to groundwater provide sufficient treatment capacity as determined per the criteria in Chapter 5.6 of this Manual. The narrative and tables in Chapter 5.6 describe the pollutant loading source area and vadose zone treatment capacity classifications that are used in making this determination. UIC facilities that discharge into geologic matrices without sufficient treatment capacity must be preceded by runoff treatment in accordance with this Core Element. Note that discharges to drywells that contain process water or other any other discharges besides stormwater will not be UIC rule-authorized and require individual permits. Discharges of stormwater from certain industrial and commercial sites to UIC facilities are be prohibited (see the complete list in Chapter 5.6); discharges of process water to UIC facilities are also prohibited. Additional local requirements may apply for any discharge to a drywell or other infiltration facility.

Basic Treatment Requirements

Runoff treatment is required for all projects creating 5,000 square feet or more of pollutant-generating impervious surfaces (PGIS) unless the discharge is to (1) a qualified UIC facility (see section above) or (2) satisfies the requirements for full dispersion (see Chapter 6, BMP F6.42) and is not a high-use site. Treatment is required for discharges to all surface waters of the state, including perennial and seasonal streams, lakes and wetlands where the PGIS threshold is met. Certain exemptions may exist for Category 4 wetlands (see later section on "Use of Existing Wetlands to Provide Runoff Treatment"). Runoff treatment is also required for discharges of stormwater to groundwater via UIC facilities where the vadose zone does not provide adequate treatment capacity (see Chapter 5.6). Project designers should also consider the possible impact of additional TSS loading from pervious areas at the project site on the long-term function of the treatment facility.

Metals Treatment Requirements

Metals treatment is required for moderate- and high-use sites (see Definitions section above) and sites that meet any of the following definitions and discharge to a non-exempt surface water:

- Industrial sites as defined by EPA (40 CFR 122.26(b)(14)) with benchmark monitoring requirements for metals; or industrial sites subject to handling, storage, production, or disposal of metallic products or other materials, particularly those containing arsenic, cadmium, chromium, copper, lead, mercury, nickel or zinc; or
- An urban road with expected ADT greater than 7,500; or a rural road or freeway with expected ADT greater than 15,000; or
- A commercial or industrial site with an expected trip end count equal to or greater than 40 vehicles per 1,000 square feet of gross building area; or a customer or visitor parking lot with equal to or greater than 100 trip ends; or on-street parking areas of municipal streets in commercial and industrial areas; or highway rest areas; or
- Runoff from metal roofs not coated with an inert, non-leachable material.

Oil Control Requirements

Oil control is required for all high-use sites (see definition above) and high ADT traffic areas. Some sites will require a spill control type of oil control facility (see Chapter 8) for source control separate from or in addition to this treatment requirement. High ADT traffic areas generate sufficient quantities of oil to threaten water quality, but the quantities of oil generated may be insufficient for many oil control BMPs to be effective; therefore these sites may employ different BMPs than are recommended for high-use sites (see Chapter 5). Projects proposing a high-use site must provide oil controls in addition to any other water quality treatment required per this Core Element.

High-use roadway intersections shall treat lanes where vehicles accumulate during the signal cycle, including left and right turn lanes and through lanes, from the beginning of the left turn pocket. If no left turn pocket exists, the treatable area shall begin at a distance equal to three car lengths from the stop line. If runoff from the intersection drains to more than two collection areas that do not combine within the intersection, treatment may be limited to any two of the collection areas where the cars stop.

High-use sites and high ADT roadways and parking areas must treat runoff from the high-use portion of the site using oil control treatment options in Chapter 5 of this Manual prior to discharge or infiltration. For high-use sites located within a larger project area, only the impervious area associated with the high-use site is subject to oil control treatment, but the flow from that area must be separated; otherwise the treatment controls must be sized for the entire area.

Phosphorus Treatment Requirements

Phosphorus treatment is required only where federal, state, or local government has determined that a water body is sensitive to phosphorus and that a reduction in phosphorus from new development and redevelopment is necessary to achieve the water quality standard to protect its beneficial uses. Where it is deemed necessary, a strategy will be adopted to achieve the reduction in phosphorus. The strategy will be based on knowledge of the sources of phosphorus and the effectiveness of the proposed methods of removing phosphorus. Contact the local jurisdiction to determine if phosphorus treatment is required for your project.

Treatment Facility Sizing

Each treatment BMP is sized based on a water quality design volume, or a water quality design flow rate. Agencies and local jurisdictions should adopt criteria to provide for consistent sizing of treatment facilities. The computational methods for predicting runoff volumes and flow rates for the proposed development condition are included in Chapter 4 of this Manual. Specific design criteria for treatment facilities also may be identified in Chapter 5 in order to achieve the performance goal of a particular BMP. Public road projects may be designed using BMPs in the 2004 (and future approved editions of the) Washington State Department of Transportation *Highway Runoff Manual* if the Core Elements for New Development and Redevelopment in this manual are met.

<u>Water quality design volume</u>: Volume-based treatment BMPs are sized the same whether located upstream or downstream from detention facilities. Each agency or local government should specify which of the following methods will be used to determine treatment volumes in their jurisdiction. If the jurisdiction has not identified a preferred method, the default method shall be Method 1 in Regions 1 and 4; and Method 2 in Regions 2 and 3.

Method 1: The volume of runoff predicted for the proposed development condition from the regional storm with a 6-month return frequency. An alternative to this method is the modified Type IA storm described in Chapter 4.2; this alternative method is intended for use on small projects where the designer's software does not accept storms longer than 24 hours.

Method 2: The volume of runoff predicted for the proposed development condition from the SCS Type IA 24-hour storm with a 6-month return frequency.

Method 3: In Regions 2 and 3, volume-based facilities may be sized for 0.5 inch predicted runoff produced for the proposed development condition from all impervious surface areas that contribute flow to the treatment facility. (This method is modified for design of BMP T5.30 Bio-infiltration swale in Chapter 5.) See Figure 2.1 for a map of the approximate delineation of the four climatic regions in eastern Washington; a more detailed map is provided in Chapter 4 (see figure 4.3.1).

Method 4: The volume of runoff predicted for the proposed development condition from the SCS Type II storm with a 6-month return frequency.

Method 5: Another sizing approach and criteria based on peer-reviewed methods and supported by local data that meet the objective of treating at least 90% of the annual volume of runoff from the site.

Snowmelt Considerations: Snowmelt should be considered in determining the water quality design volume. This is especially important in Regions 1 and 4 and also applies to other areas of eastern Washington. Check for local requirements. A snowmelt factor based on the water content of the average daily depth of snow (or based on some other appropriate measurement) should be added to the depth of precipitation for calculating runoff treatment volume; or another method described in Chapter 4.2.7 may be used.

Water quality design flow rate: Flow-rate-based treatment BMPs are sized differently depending on whether they are located upstream or downstream from detention facilities, if detention is required. Each agency or local government should specify which of the following methods will be used in their jurisdiction to size facilities preceding detention ponds. If the jurisdiction has not identified a preferred method, the default method shall be Method 1 in Regions 1 and 4; and Method 2 in Regions 2 and 3. For large facilities receiving inflow from multiple sources, the flow rate generated by the regional or Type IA storm should also be checked.

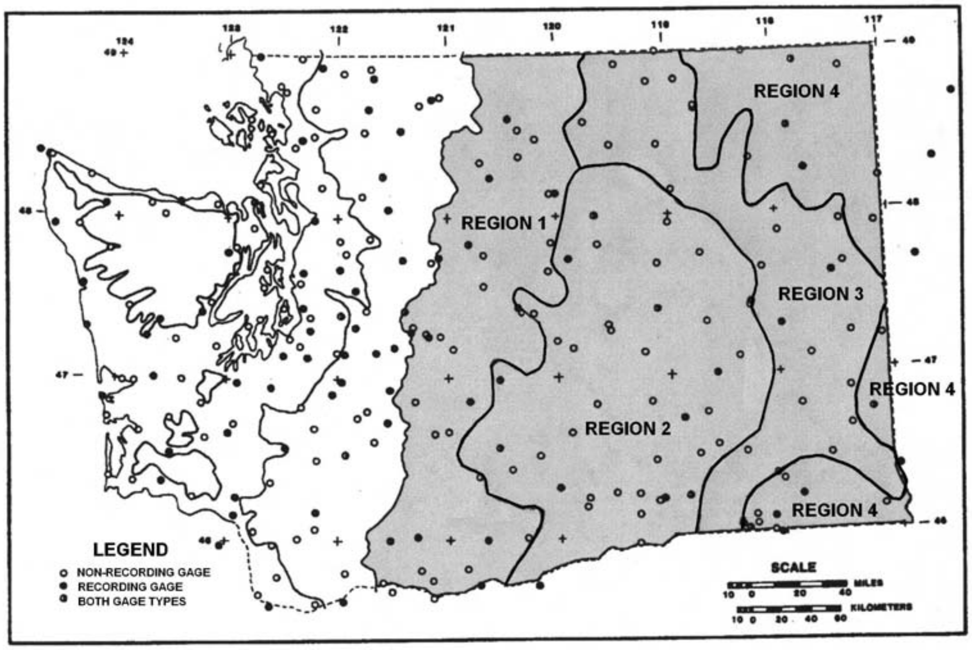

Figure 2.1 – Approximate delineation of climatic regions in eastern Washington. A more detailed map is provided in Figure 4.3.1.

For runoff treatment facilities preceding detention facilities or when detention facilities are not required:

Method 1: The runoff flow rate predicted for the proposed development condition from the short-duration storm with a 6-month return frequency. (Time intervals are specified in the BMP designs.)

Method 2: The runoff flow rate predicted for the proposed development condition from the SCS Type II 24-hour storm with a 6-month return frequency. (Time intervals are specified in the BMP designs.)

Method 3: The runoff flow rate for the proposed development condition calculated by the Rational Method using the 2-year Mean Recurrence Interval (see Chapter 4.7). This method may only be used to design facilities based on instantaneous peak flow rates.

For runoff treatment facilities sited downstream of detention facilities: The full 2-year release rate of the detention facility.

Bypass Requirements

A bypass must be provided for all treatment BMPs unless the facility is able to convey the 25-year short-duration storm without damaging the BMP or dislodging pollutants from within it. Extreme runoff events may produce high flow velocities through BMPs that can damage and or dislodge pollutants from within the facility. The designer must check the maximum allowable velocity (typically less than 2 ft/s) or shear stress specified for the BMP and implement a flow bypass as necessary to prevent exceeding these velocities. Bypass is not recommended for wet ponds, constructed wetlands, and similar volume-based treatment facilities. Inlet structures for these facilities should be designed to dampen velocities; the pond dimensions will further dissipate the energy. In these facilities, larger storms will be retained for a shorter detention time than the shorter storms for which the ponds are designed. See Chapter 5.3.1 for bypass design information.

Use of Existing Wetlands to Provide Runoff Treatment

Stormwater treatment facilities are not allowed within a wetland or its natural vegetated buffer except for:

- Necessary conveyance systems approved by the local government; or
- As allowed in a wetland mitigation plan; or
- When the requirements below are met:

<u>A wetland can be considered for use in stormwater treatment if</u>:

The wetland meets the criteria for "Hydrologic Modification of a Wetland" in Core Element #6 Flow Control;
<u>and</u> either:
It is a Category 4 wetland according to the *Eastern Washington Wetland Rating System* (see the final rating form provided on Ecology's website);
<u>or</u>:
It is a Category 3 wetland according to the *Eastern Washington Wetland Rating System* <u>and</u> the wetland has been previously disturbed by human activity, as evidenced by agriculture, fill areas, ditches *or* the wetland is dominated by introduced or invasive weedy plant species as identified in the rating analysis.

Basic treatment is required prior to discharge to Category 3 wetlands; a Category 3 wetland that meets the above requirements may be used to meet metals treatment requirements. Oil treatment required for all discharges to wetlands from high use sites (see definition).

<u>Caution</u>: Wetlands may accumulate the salts in anti-icing and deicing chemicals, so use of such chemicals should be limited in the areas discharging to the wetland (see Core Element #3 Source Control).

Mitigation is usually required for the impact of using a wetland as a stormwater treatment facility. Appropriate measures include expansion, enhancement and/or preservation of a buffer around the wetland.

Additional Requirements

Additional treatment or siting requirements may be imposed by federal, state or local governments to achieve specific water quality protection or restoration goals. Check with the local jurisdiction for additional requirements.

Supplemental Guidelines

See Chapters 4 and 5 of this Manual for detailed guidance on selection, design, construction, operation, and maintenance of treatment facilities. The water quality design volumes and flow rates are intended to size facilities to capture and effectively treat at least 90% of the annual runoff volume in eastern Washington. Facilities designed in this manner should also capture and treat nearly all of the "first flush" events.

Additional exemptions from metals treatment requirements for rural roads or small isolated commercial projects located outside Urban Growth Area boundaries may be considered on a case-by-case basis after consideration of the ability of basic treatment to protect water quality in the receiving water. Some receiving waters will have sufficient capacity to dilute the metals concentration from the cumulative stormwater discharges so water quality standards are not violated; other water bodies will not have sufficient mixing and dilution capacity. In making a determination, the local jurisdiction or other agency reviewing the project needs to consider: the average lowest monthly flow in the water body; and the existing and expected metals contributions from the surrounding area based on the zoning and probable future land use. The analysis must determine whether a water quality violation is likely to occur when a thunderstorm following an extended period of dry weather contributes polluted runoff from future build out areas to the water body during low flow conditions.

If the runoff generated from a project site by the water quality design storm discharges to a conveyance system that does not reach a surface water body or UIC facility, then basic treatment is not required. The analysis must consider all of the water flowing to the conveyance system, not just the water from the project site.

Project designers are encouraged to consider site grading, conveyance, and other design specifications that separate NPGIS from PGIS runoff to avoid treating all of the runoff from the site. Designers are also encouraged to keep PGIS runoff from portions of the site that require oil or metals treatment separate from PGIS areas that need only basic treatment where it might be possible to avoid treating all of the runoff from the site to the higher standard.

Responsibilities of Local Jurisdictions

During plan review, local jurisdictions should evaluate whether the objectives of this Core Element have been met. Staff should be aware of any current water cleanup plans (including TMDLs), sole-source aquifer protection measures, well-head protection areas or other requirements to protect or restore water quality.

Each local government should identify a preferred method for calculating (1) runoff volumes and (2) flow rates to ensure consistent sizing of treatment BMPs in their jurisdiction and to facilitate plan review. Local jurisdictions may choose to accept road projects designed per another approved equivalent manual; projects using BMPs in the 2004 Washington State Department of Transportation *Highway Runoff Manual* should still apply the Core Elements for New Development and Redevelopment in this manual. Proponents of unique or complex projects may wish to use other methodologies, and staff should work with those designers to ensure that the objectives of this Core Element are met.

Local jurisdictions are encouraged to assist in development and testing of new treatment methodologies. See Chapter 5.12 for more information.

2.2.6 Core Element #6 Flow Control

Objective

The purpose of flow control is to mitigate to the maximum extent practicable the impacts of increased storm runoff volumes and flow rates on streams in eastern Washington. The intent of this Core Element is to prevent cumulative future impacts from urban runoff; the impacts of prior development and (or) flow modifications in eastern Washington are not addressed through this Manual.

Wherever possible, infiltration is the preferred method of flow control for urban runoff. Some stream habitat problems in eastern Washington result from reduced instream flows during the hot summer months. Flow control using detention basins will not address this issue and may exacerbate it; but the cumulative effect of infiltrating urban runoff should have a neutral or possibly beneficial effect.

This Core Element is targeted to smaller water bodies, especially first to third order streams or water bodies with contributing watershed areas of less than 100 square miles. These streams are more susceptible to changes in runoff patterns caused by development.

This Core Element is also targeted to wetlands. Discharges to wetlands should maintain the hydrology (depth and duration of inundation) of the existing condition in order to protect the unique vegetation and other characteristics necessary to support existing and designated uses.

Design specifications for conveyance and flood prevention are determined by local jurisdictions. This Core Element does not address those issues.

Exemptions

Flow control is not required for all discharges to surface waters in eastern Washington because flow control is not always needed to protect stream morphology. The exemptions listed below are provided to assist local jurisdictions in determining which projects should be subjected to this Core Element. Any project may be subject to local requirements for flow control to prevent flooding. All projects are encouraged to infiltrate storm runoff on site to the greatest extent possible.

In consideration of other environmental issues, a local jurisdiction may wish to require flow control for one or more of the types of projects or water bodies listed below. Conversely, following analysis of a particular water body and/or its watershed, a local jurisdiction may determine that flow control is not necessary for certain discharges or to protect certain water bodies, or decide to provide a regional stormwater facility instead of requiring site-by-site flow control facilities. See additional information in the supplemental guidelines.

<u>The following projects and discharges are exempt from flow control requirements to protect stream morphology</u>. Runoff treatment may still be required per Core Element #5. Local jurisdictions may override any exemptions.

1. Any project able to disperse, without discharge to surface waters, the total 25-year runoff volume for the proposed development condition on property that is under the functional control of the project proponent. See the guidelines for dispersion in Chapter 6.5, particularly BMP F6.42.

2. A road project able to disperse, without discharge to surface waters, the total 25-year runoff volume for the proposed development condition on land for which this use has been specifically authorized by the controlling entity. See the guidelines for dispersion in Chapter 6.5 and the 2004 (and future revisions of) Washington State Department of Transportation *Highway Runoff Manual*.

3. A project constructing less than 10,000 square feet of total impervious surfaces. Local jurisdictions may establish a different impervious surface area threshold (see Core Element #8 Local Requirements).

4. A project discharging to stream reaches consisting primarily of irrigation return flows and not providing habitat for fish spawning and rearing. Projects should match the pre-developed or existing condition 2-year and 25-year peak runoff rates for these discharges. The local irrigation district may impose other requirements.

5. A project discharging <u>directly</u> to:
   - Any of the rivers or lakes on the list of exempt surface waters below; or
   - Reservoirs on the Columbia, Snake, Pend Oreille, or Spokane rivers; or
   - Other reservoirs with outlet controls that are operated for varying discharges to the downstream reaches as for hydropower, flood control, irrigation, or drinking water supplies. Uncontrolled, flow-through impoundments are not exempt.

Projects may also discharge to these waters through a publicly owned conveyance system with sufficient capacity; permission must be granted by the owner/operator of the conveyance system.

In order to be exempted, the discharge must meet all of the following requirements:

a. The project area must be drained by a conveyance system that is comprised entirely of manmade conveyance elements (e.g., pipes, ditches, outfall protection); and
b. The conveyance system must extend to the ordinary high water line of the receiving water, or (in order to avoid construction activities in sensitive areas) flows are properly dispersed before reaching the buffer zone of the sensitive or critical area; and
c. Any erodible elements of the conveyance system for the project area must be adequately stabilized to prevent erosion; and
d. Surface water from the project area must not be diverted from or increased to an existing wetland, stream, or near-shore habitat sufficient to cause a significant adverse impact. Adverse impacts are expected from uncontrolled flows causing a significant increase or decrease in the 1.5- to 2-year peak flow rate.

Exempt surface waters:
Asotin Creek downstream of confluence with George Creek
Banks Lake
Bumping River downstream of confluence with American River
Lake Chelan
Cle Elum River downstream of Cle Elum Lake
Columbia River
Colville River downstream of confluence with Chewelah Creek
Grande Ronde River
Kettle River downstream of confluence with Boulder Creek
Klickitat River downstream of confluence with West Fork
Latah Creek (formerly called Hangman Creek) downstream of confluence with Rock Creek (in Spokane County)
Little Spokane River downstream of confluence with Deadman Creek
Lower Crab Creek
Methow River downstream of confluence with Early Winters Creek
Moses Lake
Naches River downstream of confluence with Bumping River
Okanogan River
Palouse River downstream of confluence with South Fork Palouse River
Pend Oreille River
Potholes Reservoir
Rock Creek (in Whitman County) downstream of confluence with Cottonwood Creek
Similkameen River

Snake River
Spokane River
Teanaway River downstream of confluence of north and west forks
Tieton River downstream of Rimrock Lake
Toppenish Creek downstream of confluence with Wanity Slough
Touchet River downstream of confluence with Patit Creek
Tucannon River downstream of confluence with Pataha Creek
Walla Walla River downstream of confluence with Mill Creek
Wenatchee River downstream of confluence with Icicle Creek
Yakima River downstream of Lake Easton

This list of exempt water bodies is generally comprised of fifth or greater order stream channels (determined from a 1:150,000 scale map) and lakes with watershed areas much greater than 100 square miles. The list is subject to change as more information is gathered. See the Supplemental Guidelines at the end of this section for an alternate definition of a "large" exempt stream.

6. A project discharging to a wetland that has no surface water outlet does not need to meet the flow control requirements to protect stream morphology. Flow control may still be required to protect the wetland (see Core Element 4 Protection of Natural Drainage Systems and Outfalls and also the guidelines for wetlands below).

7. A project located at a site with less than 10" average annual rainfall that discharges to a seasonal stream which is not connected via surface flow to a non-exempt surface water by runoff generated by the 2-year Type IA storm.

8. A project that discharges to a stream which flows only during runoff-producing events. The runoff carried by the stream following the 2-year regional storm in Regions 1 and 4, or the Type IA storm in Regions 2 and 3, must not discharge via surface flow to a non-exempt surface water. The stream may carry runoff during an average annual snowmelt event but must not have a period of baseflow during a year of normal precipitation.

Any additional exemptions to and overriding of this Core Element are left to the local jurisdiction based on basin planning and studies (see Supplemental Guidelines). These plans and studies should consider: the total impervious area in the watershed under likely future development scenarios; other possible development impacts or contributions toward increasing future streamflow volumes and changing the stream channel morphology and/or increasing the potential for streambank erosion; other potential cumulative downstream effects; and unique habitat characteristics.

Guidelines

Non-exempt projects shall construct stormwater flow control facilities for any discharge of stormwater directly, or through a conveyance system, into surface water. Discharges to groundwater are exempt from the flow control requirements of this Manual, but may be subject to design specifications or other restrictions established by local jurisdictions. Flow control facilities shall be selected, designed, constructed, operated and maintained according to the criteria in Chapters 4 and 6. The requirements below apply to projects whose stormwater discharges into a non-exempt surface water, either directly or indirectly through a natural or man-made conveyance system. For a list of exempt surface waters, see the Exemptions section above.

In order to prevent localized erosion, energy dissipation at the point of discharge is required for all projects unless site-specific conditions warrant an exception (see also Core Element #4 Preservation of Natural Drainage Systems).

When this Core Element is required, Core Element #7 Operation and Maintenance is also required.

Hydrologic Analysis

Pre-development or existing and proposed-development condition runoff volumes and flow rates shall be estimated using the methods described in Chapter 4 of this manual or by an alternate method approved by the local jurisdiction. Existing conditions at the site are used for the analysis unless the local jurisdiction has imposed other requirements. The design storm for determining both volumes and flow rates in Regions 1 and 4 is the regional storm (an acceptable alternative for small projects when the designer's software does not accept a storm longer than 24 hours is the modified Type IA storm described in Chapter 4.2); the design storm for Regions 2 and 3 is the Type IA storm. A custom design storm or modeling approach based on historical data or rainfall-runoff studies for a certain watershed may also be applied where adopted by an agency or local government. See Chapter 6 for pond and release structure design information.

Application to Non-Exempt Streams

To protect stream morphology, projects shall limit the peak rate of runoff to 50% of the pre-developed or existing 2-year peak flow and maintain the pre-developed or existing 25-year peak runoff rate. The entire 2-year runoff volume from the proposed development condition shall be released at no more than 50% of the pre-developed or existing 2-year peak flow rate. The design storm to be used is the regional storm in Regions 1 and 4 or the Type IA storm in Regions 2 and 3. Existing conditions at the site are used for the analysis unless the local jurisdiction has imposed other requirements. A custom design storm or modeling approach based on historical data or rainfall-runoff studies for a certain watershed may also be applied where adopted by an agency or local government. An agency or local jurisdiction also may require detention basins to be designed to match a different return-interval (e.g. 10-year, 50-year, or 100-year) peak flow rate instead of or in addition to the 25-year peak flow rate. In all cases where the discharge is to non-exempt streams, detention basins must be designed to release no more than 50% of the 2-year peak flow rate for the pre-developed or existing condition.

Application to Wetlands and Lakes

To protect wetland hydrology, if the wetland does not have an outlet to a stream or has a direct outlet to an exempt river or lake, the project shall maintain the pre-developed or existing 2-year and 25-year peak runoff rates for the regional storm in Regions 1 and 4 or the Type IA storm in Regions 2 and 3. If the wetland has an outlet to a non-exempt stream, the project shall meet the flow control design requirement above to protect the stream. Category 3 or 4 wetlands may be excluded from this requirement and used as detention and(or) treatment facilities if the criteria below for "Hydrologic Modification of a Wetland" (and in Core Element #5, for treatment) are met. Discharges to lakes shall maintain the pre-developed or existing 2-year and 25-year peak runoff rates for the regional storm in Regions 1 and 4 or the Type IA storm in Regions 2 and 3. An agency or local jurisdiction also may require detention basins to be designed to match a different return-interval (e.g., 10-year, 50-year, or 100-year) peak flow rate instead of or in addition to the 25-year peak flow rate for discharges to either lakes or wetlands.

Considerations for Very Low Flow Rates

In many cases the 2-year pre-developed or existing condition flow rate is zero cubic feet per second, or the flow rate is so small that it is impracticable to design a pond to release at the prescribed flow rate from an engineered outlet structure. In these cases the total 2-year storm runoff volume from the proposed development condition must be infiltrated (preferred) or stored in a retention pond for evaporation, and the detention pond designed to release the pre-developed 10-year and 25-year flow rates. An agency or local jurisdiction also may require detention basins to be designed to match different return-intervals (e.g., match only the10-year, or match the 50-year or 100-year peak flow rate instead of or in addition to the 25-year peak flow rate).

Hydrologic Modification of a Wetland

Hydrologic modification of a wetland for the purpose of stormwater management means that the wetland will receive a greater total volume of surface runoff following the proposed development than it receives in the current condition (see Chapter 4 Hydrologic Analysis). Hydrologic modification is not allowed if the wetland is classified as Category 1 or 2 according to the *Eastern Washington Wetland Rating System* (see the final rating form provided on Ecology's website) unless the project proponent demonstrates that preferred methods of excess stormwater disposal (e.g., infiltration) are not possible at the site and that other options (e.g., evaporation) would result in more damage to the wetland by limiting baseflow.

A wetland can be considered for hydrologic modification if it is a Category 3 or 4 wetland according to the *Eastern Washington Wetland Rating System* and:

- There is good evidence that the natural hydrologic regime of the wetland can be restored by augmenting its water supply with excess stormwater runoff; or the wetland is under imminent threat exclusive of stormwater management and could receive greater protection if acquired for a stormwater management project rather than left in existing ownership;

and:

- The runoff is from the same natural drainage basin; the wetland lies in the natural routing of the runoff; and the site plan allows runoff discharge at the natural location. Exceptions may be made for regional facilities planned by the local jurisdiction, but the wetland should receive water from sites in the same watershed.

Mitigation is usually required for the impact of hydrologic modification to a wetland. Appropriate measures include expansion, enhancement and/or preservation of a buffer around the wetland.

Applicability to UIC Facilities

This Core Element does not apply to projects using drywells and other UIC rule-authorized subsurface infiltration systems. See Chapter 6 for supplemental guidance on sizing drywells.

Supplemental Guidelines

Local jurisdictions may adopt a conservative, restricted set of curve numbers for estimating runoff volumes and flow rates from pre-development or existing conditions. Ecology recommends that local jurisdictions consider applying natural vegetative cover pre-development conditions. Natural vegetative cover has a moderating influence on runoff generation during rain-on-snow events, and changes in cover should be a primary consideration in evaluating the change in runoff volumes caused by development in many areas of eastern Washington.

The local jurisdiction or project proponent may evaluate the substrate of a stream to determine whether the requirement to release the 2-year peak volume for the proposed development condition at 50% of the 2-year peak flow rate for the pre-development or existing can and should be adjusted. The release rate of 50% of the 2-year peak flow rate is a middle ground that should be protective for most streams and was chosen for its ease of application. However, for a highly erodible substrate such as sand or loess the target should be closer to 20% of the 2-year peak flow rate; and for an erosion-resistant substrate such as clay, the target could be closer to 90% of the 2-year peak flow rate. The substrate should be evaluated for a minimum distance of one-half mile downstream of the proposed discharge. The focus of the study should be on evaluating the erodibility of the downstream substrate under the probable build-out conditions to at least the next significant natural inflow, and the results considered together with studies and findings by Leopold *et. al.* (1964), Williams (1978), Harvey and Watson (1986), Hammer (1972), Bledsoe and Watson (2001), Booth (1997), and Cappuccitti and Page (2000) in making the determination.

In order to reduce potential effects of increased water temperatures during the hot summer months, projects should consider withholding the total runoff volume for the proposed development condition from the 2-year short-duration storm in the detention facility for infiltration (preferred) and(or) evaporation.

To meet the flow control target, optimal placement of multiple small-scale retention/infiltration facilities within a drainage area may require less total storage capacity than a single detention pond at the drainage outlet.

A number of proven and emerging “Low Impact Development” (LID) techniques may be applied at sites in eastern Washington to reduce impervious surface areas and minimize the increase in runoff rates from a project site. Such techniques include use of porous pavement, grassed pavers, and curb cuts to small surface depressions instead of raised planting beds in parking areas. See Ecology’s, the U.S. Environmental Protection Agency’s or the Puget Sound Water Quality Action Team’s websites for additional information about LID approaches and links to demonstration projects and research activities. The Washington State Department of Transportation also included a section on LID techniques for roads in the 2004 *Highway Runoff Manual*.

Local jurisdictions may require detention basins to be designed to match the 10-year peak flow in addition to 50% of the 2-year peak flow and the full 25-year peak flow. The purpose of this design specification is to improve the function of the detention basin in matching predeveloped peaks between 50% of the 2-year peak flow and the full 25-year peak flow and possibly reduce the size of the detention facility.

Regulatory agencies and local jurisdictions may exempt additional streams from this Core Element by applying the following definition of a “large” stream (see exemption #5):

- Any river or stream that is fifth order or greater as determined from a 1:24,000 scale map; or
- Any river or stream that is fourth order or greater as determined from a 1:100,000 or larger scale map.

The maps should be standard USGS maps or GIS data sets derived from USGS base maps. The other provisions of exemption #5 must still be applied, and consideration should also be given to other information about the stream bed material and downstream channel conditions.

Local jurisdictions may engage in basin planning, studies, zoning restrictions, etc., that result in watershed- or reach- specific changes to the requirements of this Core Element. These studies may also address the question of whether low streamflow problems may be aggravated by flow control requirements for certain streams.

Additional exemptions to this Core Element may be granted to projects discharging to surface water where the long-term, projected total man-made impervious surface area in the contributing watershed is less than 5% of the total area, and at least 65% of the natural vegetative cover is retained. This determination must be based on current and probable future zoning requirements and build out conditions as determined through a basin analysis conducted by the local jurisdiction (see below). This analysis could also be done for a road project in a rural area; although dispersion (see Chapter 6.5, particularly BMP F6.42) would be preferable to conveyance of runoff to a non-exempt stream.

Local jurisdictions may also exempt a project discharging to a seasonal stream where downstream analysis has concluded that the stream channel morphology was established by past glacial or catastrophic flooding events and the stream channel is capable of carrying a larger frequent streamflow without incision or widening. The stream must not discharge via surface flow to a non-exempt stream.

Suggested Approach for Additional Exemptions

In order for a jurisdiction to exempt other water bodies or reaches from flow control requirements, the local jurisdiction must provide scientific justification for the exemption. (The exemption may apply only to restricted areas within a watershed.) This means the jurisdiction must determine that under probable build-out conditions in the watershed, disregarding this Core Element will not adversely affect the receiving waters. Adverse impacts are expected from uncontrolled flows causing a significant increase in the 1.5- to 2-year recurrence interval peak instream flow rate. Documentation must be provided showing that significant increases in instream flow rates will not take place under the maximum projected development condition for the contributing watershed. The documentation should at least include the following elements:

- Analysis of available historical streamflow data for the water body (for a lake, the outlet stream may be the primary water body of interest for flow control) and hydrologic modeling of the watershed under both undeveloped and projected future build-out conditions.
- Observation of downstream channel conditions, including: assessment of the geomorphic conditions, instream habitat, and resident benthic community.
- Maps or geographic analyses showing:
  - current and probable future zoning (with definitions for density of development in each category);
  - the portion of watershed under the jurisdiction of the petitioner;
  - projected total man-made impervious surface areas; and
  - area of native vegetation preserved under probable future build-out conditions.

- Description of the watershed planning efforts undertaken by the petitioning jurisdiction and cooperative planning efforts undertaken with other agencies and jurisdictions with authority in the watershed.

A local jurisdiction also should consider and utilize the above information in planning and designing a regional flow facility, and in particular for determining the appropriate capacity and operation requirements of the facility.

Responsibilities of Local Jurisdictions

During plan review, local jurisdictions should evaluate whether the objectives of this Core Element have been met. Local jurisdictions should establish design criteria for conveyance systems, flood protection, and drywells and other UIC facilities.

In particular, local governments should determine whether the default design criterion of the 25-year runoff volume for detention/retention flow control facilities is appropriate to meet local flood protection goals and, if it is not, establish a different upper boundary design criterion.

Local governments should consider establishing an impervious area threshold below which projects are not required to provide flow control facilities. The exemption should be based on an evaluation for the local area of the amount of impervious surface area necessary to generate an appreciable change in runoff from the 6-month and 2-year regional or Type IA storm events. Alternatively, a project generating less than 0.1 cfs increase in runoff for the 25-year storm could be exempt.

Local governments should also determine whether the default design criteria for drywells in Chapter 6 are appropriate to meet local goals. In particular, knowledge of local geology and groundwater levels may lead to specific siting and infiltration capacity requirements, or to development of presumptive infiltration rates for certain areas in the local jurisdiction. These criteria and local information should be made readily available to designers.

2.2.7 Core Element #7
Operation and Maintenance

Objective

Inadequate maintenance or improper operation is a common cause of failure for stormwater facilities, including drywells. To ensure that stormwater control facilities are adequately maintained and properly operated, projects are required to plan for and perform appropriate preventive maintenance and performance checks at regular intervals.

Guidelines

Where structural BMPs are required, projects shall operate and maintain the facilities in accordance with an Operation and Maintenance (O&M)

plan that is prepared in accordance with the provisions in Chapters 5 and 6 of this Manual. The O&M plan shall address all proposed stormwater facilities and BMPs, and identify the party (or parties) responsible for maintenance and operation; the O&M plan must also address the long-term funding mechanism that will support proper O&M. At private facilities, a copy of the plan shall be retained onsite or within reasonable access to the site, and shall be transferred with the property to the new owner. For public facilities, a copy of the plan shall be retained in the appropriate department. A log of maintenance activity that indicates what actions were taken shall be kept and be available for inspection by the local jurisdiction.

The local jurisdiction may develop a generic O&M plan for BMPs that are commonly used in public projects; commercial and residential property developers may also develop generic O&M plans for BMPs that are commonly used in their projects. Checklists of O&M actions and procedures may be helpful to the operators.

Applicability to UIC Facilities

This Core Element is required for all projects with discharges to drywells and other UIC rule-authorized subsurface infiltration systems that require a two-stage drywell or runoff pre-treatment (see Chapter 5.6).

Supplemental Guidelines

The description of each BMP in Chapters 5, 6, and 7 of this Manual includes a section on maintenance. Chapter 6 includes a schedule of maintenance standards for drainage facilities. Local jurisdictions should consider more detailed requirements for maintenance logs, such as a record of where wastes are disposed.

Responsibilities of Local Jurisdictions

As part plan review and approval, local jurisdictions should consider requiring a performance bond for operation and maintenance of BMPs at the site (see section 2.3.1 Financial Liability). Staff can enforce proper operation and maintenance requirements during site inspections or in response to complaints about a site or facility.

2.2.8 Core Element #8 Local Requirements

Objective

This manual describes the minimum Core Elements for stormwater management at project sites in eastern Washington. Due to the variety in hydrology, climate, topography, soils, and priorities for protection of water resources in some areas of eastern Washington, discretion is provided to local jurisdictions in expanding and implementing stormwater requirements.

Guidelines

All projects, regardless of size, shall meet additional local requirements for flood control, discharges to wetlands, protection of sensitive areas, basin plans, aquifer protections, special water quality requirements based on Total Maximum Daily Load (TMDL) or Water Cleanup Plan, or for any other purpose. Check with the local jurisdiction for the local requirements that are applicable to your project.

Applicability to UIC Facilities

This Core Element is required for all projects with discharges to drywells and other UIC rule-authorized subsurface infiltration systems.

Responsibilities of Local Jurisdictions

The following specific local requirements, if identified, should be made readily available to project proponents and designers:

- Simplified Stormwater Site Plans (SSPs) or Construction Stormwater Pollution Prevention Plans (SWPPPs) that may have been developed for specific types of projects;
- Actions required under current water clean-up plans (such as TMDLs) or other measures necessary to protect or restore water quality;
- Sole-source aquifer protection requirements and(or) well-head protection area requirements;
- Preferred methods for calculating runoff volumes and flow rates to ensure consistent sizing of treatment BMPs within the jurisdiction;
- A determination of whether a downstream jurisdiction’s requirements may apply when jurisdictions have interconnected storm sewer systems (neighboring jurisdictions should work together to establish consistent design criteria for stormwater facilities since hydrologic conditions are likely to be similar);
- Development and testing of new treatment methodologies that may be underway;
- Information on Low Impact Development (LID) techniques that could reduce the amount of impervious surface area at projects;
- Design criteria for conveyance systems and flood prevention;
- Design criteria for drywells, particularly infiltration capacity requirements and related local geologic information;
- Any alternative impervious area or other threshold below which projects are not required to provide flow control facilities;
- Additional exemptions (or exceptions) to the list of exempt surface waters;
- Detailed operation and maintenance requirements; and
- Any other adjustments to the Core Elements or to the Redevelopment requirements in section 2.1.2.

2.3 Optional Guidance

The following guidance is offered as recommendations to local jurisdictions.

2.3.1 Financial Liability

Performance bonding or other appropriate financial guarantees should be required for all private development projects to ensure construction of drainage facilities in compliance with these standards. The type of financial instrument required is less important than ensuring there are adequate funds available in the event that performance is unsatisfactory or non-compliance occurs.

2.3.2 Adjustments

Adjustments to the Core Elements may be granted prior to permit approval and construction. The drainage manual administrator of the local jurisdiction may grant an adjustment provided that a written finding of fact is prepared, that addresses the following:

- The adjustment provides substantially equivalent environmental protection, and
- The objectives of safety, function, environmental protection and facility maintenance, based upon sound engineering, are met.

2.3.3 Thresholds

Local jurisdictions may decrease the size of regulated projects and increase the number of requirements.

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Chapter 3 - Preparation of Stormwater Site Plans

3.1 Introduction

The Stormwater Site Plan is the comprehensive report containing all of the technical information and analysis necessary for regulatory agencies to evaluate a proposed new development or redevelopment project for compliance with stormwater requirements. Contents of the Stormwater Site Plan will vary with the type and size of the project, individual site characteristics, and special requirements of the local jurisdiction.

The scope of the Stormwater Site Plan also varies depending on the applicability of Core Elements (see Chapter 2).

This chapter describes the contents of a Stormwater Site Plan and provides a general procedure for how to prepare the plan. The specific BMPs and design methods and standards to be used are contained in Chapters 4 to 8.

The goal of this chapter is to provide a framework for uniformity in plan preparation. Such uniformity will promote predictability throughout the region and help secure prompt governmental review and approval. Properly drafted engineering plans and supporting documents will also facilitate the operation and maintenance of the proposed system long after its review and approval.

State law requires that engineering work be performed by or under the direction of a professional engineer licensed to practice in Washington State. Plans involving construction of treatment facilities or flow control facilities (detention ponds or infiltration basins), structural source control BMPs, or drainage conveyance systems generally involve engineering principles and shall be prepared by or under the direction of a licensed engineer. Construction Stormwater Pollution Prevention Plans (SWPPPs) that involve engineering calculations must also be prepared by or under the direction of a licensed engineer.

3.2 Stormwater Site Plans: Step-By-Step

3.2.1 The Steps to Developing a Stormwater Site Plan

Four basic steps should be followed during the preparation of a stormwater site plan.

Step 1 – Collect and Analyze Information on Existing Conditions

Step 2 – Determine Applicable Core Elements

Step 3 – Prepare a Permanent Stormwater Control Plan

Step 4 – Prepare a Construction Stormwater Pollution Prevention Plan

Steps 1 and 2 are qualtitative in nature, while Steps 3 and 4 synthesize the information gathered in Steps 1 and 2 into practical designs. Additional information on data collection and investigation can be found in Design and Construction of Urban Stormwater Management Systems, ASCE, 1992. The level of detail needed for each step depends upon the project size, as explained in the individual steps. A narrative description of each of these steps follows.

Step 1 – Collect and Analyze Information on Existing Conditions

Collect and review information on the existing site conditions including: topography, drainage patterns, soils, ground cover, presence of critical areas, adjacent areas, existing development, existing stormwater facilities, and adjacent on- and off-site utilities. Analyze data to determine site limitations including:

- Areas with high potential for erosion and sediment deposition (based on soil properties, slope, etc.);
- Locations of sensitive and critical areas (e.g., vegetative buffers, wetlands, steep slopes, floodplains, geologic hazard areas, streams, etc.);
- Observation of potential runoff contribution from off-site basins;
- Adjacent properties and(or) projects that have a history of stormwater problems, noting whether the cause of the problem(s) has been determined; and
- Adjacent properties and(or) projects where geotechnical investigations have identified shallow bedrock, high groundwater, seasonally perched groundwater, or clay lenses in the substrata.

Delineate these areas on the site map required as part of Step 3, Prepare a Permanent Stormwater Control Plan. Prepare an Existing Conditions Summary that will be submitted as part of the Site Plan. Part of the information collected in this step should be used to help prepare the Construction Stormwater Pollution Prevention Plan.

Downstream Analysis and Mitigation Procedure (for projects with surface, offsite, or potential problem discharges)

Development projects that propose to discharge stormwater offsite are required to submit a downstream analysis report that assesses the potential off-site water quality, erosion, slope stability, and drainage impacts associated with the project and that proposes appropriate mitigation of those impacts. An initial qualitative analysis should extend downstream for the entire flow path from the project site to the receiving water, or up to one mile or to a point where the impact to receiving waters are minimal or nonexistent, as determined by the local jurisdiction. If a receiving water is within one-quarter mile, the analysis should extend within the receiving water to one-quarter mile from the project site. The analysis should extend one-quarter mile beyond any improvements proposed as mitigation. The analysis should extend upstream to a point where backwater effects created by the project cease. Upon review of the qualitative analysis, the local jurisdiction may require that a quantitative analysis be performed. A full description of a typical downstream analysis procedure, along with a sample checklist to aid in the preparation and review of a downstream analysis, are included in Appendix 3A.

Step 2 – Determine and Read the Applicable Core Elements

The NPDES Phase II permit or local jurisdiction establishes project size thresholds for the application of Core Elements (in Chapter 2), to new development and redevelopment projects. The designer of the Stormwater Site Plan should meet with local officials to agree on the applicable Core Elements, prior to proceeding to Step 3.

Step 3 – Prepare a Permanent Stormwater Control Plan

Select stormwater control BMPs and facilities that will serve the project site in its developed condition. The designer may want to consider the use of landscaping and/or low impact development techniques for stormwater quantity and quality control. The local jurisdiction may have landscaping or low impact development policies and they should be incorporated where required. Several references are available on the topic of low impact development:

www.lowimpactdevelopment.org/

www.epa.gov/owow/nps/lid/lid.pdf

www2.ncsu.edu/ncsu/CIL/WRRI/news/so00lowimpactmanuals.html

A preliminary design of the BMPs and facilities is necessary to determine how they will fit within and serve the entire preliminary development layout. After a preliminary design is developed, the designer may want to reconsider the site layout to reduce the need for construction of facilities, or the size of the facilities by reducing the amount of impervious surfaces created and increasing the areas to be left undisturbed. After the designer is satisfied with the BMP and facilities selections, the information must be presented within a Permanent Stormwater Control Plan. The Permanent Stormwater Control Plan typically consists of a Drainage Report and a set of Construction Plans.

Drainage Report

The Drainage Report is to be inclusive, clear, legible, and reproducible, with a complete set of drainage computations and stamped by a Professional Engineer. The computations are to be presented in a rational format with information included so as to allow a reviewer to be able to reproduce the same results. The computations should provide sufficient information for an unbiased third party to be able to review the report and determine that all applicable standards have been met. All assumptions and computer input and output data, and variables listed in the computer printouts, should be clearly identified. Computer printouts should clearly show which subbasin(s) they are applicable to, and the design storm event identified thereon if multiple-storm events are addressed in the design. Copies of design charts, nomographs, or other design aids used in the analysis should be included in the calculations.

All relevant geotechnical information related to the project and all site specific soil logs and subsurface testing information should be included in the Drainage Report or provided in a separate report prepared and stamped by the geotechnical engineer or Licensed Engineering Hydrogeologist.

The Drainage Report should also include a basin map. Under most conditions both a pre-developed basin map and post-developed basin map should be provided, unless deemed unnecessary by the local jurisdiction. See Appendix 3B for a checklist of items to be included on the basin map.

The Drainage Report is to identify existing drainage facilities which are clearly inadequate or need repair, such as collapsed culverts or culverts with a substantial amount of debris. The condition and capacity of existing drainage facilities located onsite, which are proposed to be utilized by the development, should be evaluated and disclosed in the drainage report.

Calculations for detention and infiltration ponds may include the following: inflow and outflow hydrographs, level-pool routing calculations, a listing of the maximum water surface elevation, a pond volume rating table (e.g., stage vs. storage), and discharge rating table (e.g., stage vs. discharge). Each hydrograph and level-pool routing calculation sheet is to have clearly marked: the design storm event, the applicable subbasin(s), and the pond identification name, which corresponds with the basin map and plans.

The drainage submittal should incorporate all calculations for the determination of the required size of the systems. Typical calculations include:

- Hydrology computations
- Inlet capacities
- Detention/Retention storage capacities
- Culvert and pipe system capacities and outlet velocities
- Ditch capacities and velocities
- Map with the project plotted thereon

A copy of applicable floodplain maps, or studies within the project area should be included in the Drainage Report.

Construction Plans

Construction plans should be prepared for all open and closed stormwater collection systems. The plans should call out sufficient hydraulic and physical data for construction of the system and future evaluation of the design. A checklist describing many of the items typically shown on construction plans is included in Appendix 3C.

Step 4 – Prepare a Construction Stormwater Pollution Prevention Plan

The Construction SWPPP must contain sufficient information to satisfy the local jurisdiction that the potential pollution problems have been adequately addressed for the proposed project. An adequate Construction SWPPP includes a narrative and drawings. The narrative is a written statement that explains the pollution prevention decisions made for a particular project. The narrative contains concise information concerning existing site conditions, construction schedules, and other pertinent items that are not contained on the drawings. The drawings and notes describe where and when the various BMPs should be installed, the performance the BMPs are expected to achieve, and actions to be taken if the performance goals are not achieved.

The 12 Elements listed below must be considered in the development of the Construction SWPPP unless site conditions render the element unnecessary and the exemption from that element is clearly justified in the narrative of the Construction SWPPP. These elements are described in detail in Chapter 7. They cover the general water quality protection strategies of limiting site impacts, preventing erosion and sedimentation, and managing activities and sources.

The 12 Elements are:

- Mark Clearing Limits
- Establish Construction Access
- Control Flow Rates
- Install Sediment Controls
- Stabilize Soils
- Protect Slopes
- Protect Drain Inlets
- Stabilize Channels And Outlets
- Control Pollutants
- Control De-Watering
- Maintain BMPs
- Manage the Project

A complete description of each Element and the BMPs applicable to particular Elements are given in Chapter 7.

On construction sites that discharge to surface water, the primary consideration in the preparation of the Construction SWPPP is compliance with the state Water Quality Standards. The step-by-step procedure outlined in Chapter 7 is recommended for the development of these Construction SWPPPs. A checklist is contained in Chapter 7 that may be helpful in preparing and reviewing the Construction SWPPP.

On construction sites that infiltrate all stormwater runoff, the primary consideration in the preparation of the Construction SWPPP is the protection of the infiltration facilities from fine sediments during the construction phase and protection of ground water from other pollutants. Several of the other elements are very important at these sites as well, such as marking the clearing limits, establishing the construction access, and managing the project.

Under current federal regulations, if a project disturbs greater than one acre and discharges to surface water, the local jurisdiction may require review and approval of the SWPPP prior to construction.

3.2.2 Plans Required After Stormwater Site Plan Approval

This section includes the specifications and contents required of those plans submitted after the local government agency with jurisdiction has approved the original Stormwater Site Plan.

Stormwater Site Plan Changes

If the designer wishes to make changes or revisions to the originally approved stormwater site plan, the proposed revisions should be submitted to the local jurisdiction with review authority prior to construction. The submittals should include the following:

1. Brief narrative description of the change and the purpose/reason for the change.
2. Substitute pages of the originally approved Stormwater Site Plan that include the proposed changes.
3. Revised drawings showing structural changes.
4. Other supporting information that explains and supports the reason for the change.

Final Corrected Plan Submittal

If the project included construction of conveyance systems, treatment facilities, flow control facilities, or structural source control BMPs, the applicant should submit a final corrected plan (Record Drawings) to the local government agency with jurisdiction when the project is completed. These should be engineering drawings that accurately represent the project as constructed. These corrected drawings must be legibly drafted revisions that are stamped, signed, and dated by a licensed engineer registered in the state of Washington.

Appendix 3A – Downstream Analysis

Objective: To identify and evaluate potential offsite water quality, erosion, slope stability, and drainage impacts that could result from the proposed project, and to determine measures to mitigate potential impacts or mitigate aggravating existing problems. Aggravated means increasing the frequency of occurrence and/or severity of an already existing problem.

Guidelines: Some of the common negative impacts of land development can be erosion of downgradient properties, localized flooding, and slope failures. These are caused by increased volumes of surface water, increased volumes of stormwater injected into the subsurface, and(or) changed runoff patterns. Taking the precautions of offsite analysis can reduce future property damage and public safety risks.

The existing or potential impacts to be evaluated and mitigated should include:

- Conveyance system capacity problems;
- Localized flooding;
- Upland erosion impacts, including landslide hazards;
- Stream channel erosion at the outfall location;
- Violations of surface water quality standards as identified in a Basin Plan or a TMDL (Water Cleanup Plan); or violations of groundwater standards in a wellhead protection area, or any other known violation that exists;
- Aggravated existing problems.

Projects are required to initially submit, with the permit application, a qualitative analysis of each downstream system leaving the site. The analysis should accomplish four tasks:

Task 1 – Define and map the study area.

A submission of a site map showing site property lines; a topographic map (at a minimum a USGS 1:24000 Quadrangle Topographic map) showing site boundaries, study area boundaries, downstream flowpath, and potential/existing problems.

Task 2 – Review all available information on the study area.

This should include all available basin plans, groundwater management area plans, drainage studies, floodplain/floodway FEMA maps, wetlands inventory maps, Critical Areas maps, stream habitat reports, etc. Contact the local jurisdiction for assistance in locating these and other relevant or historical data.

Task 3 – Field inspect the study area.

The design engineer or engineering geologist must physically inspect the existing on- and offsite drainage systems of the study area for existing or potential problems and drainage features. An initial inspection and investigation should include:

- Investigate problems reported or observed during the resource review;
- Locate existing/potential constrictions or capacity deficiencies in the drainage system;
- Identify existing/potential flooding problems;
- Identify existing/potential overtopping, scouring, bank sloughing, or sedimentation;
- Identify significant destruction of aquatic habitat (e.g., siltation, stream incision);
- Collect qualitative data on features such as land use, impervious surface, topography, soils, presence of streams, wetlands;
- Collect information on pipe sizes, channel characteristics, drainage structures;
- Verify tributary drainage areas identified in Task 1;
- In some cases it may be required or appropriate to contact the local jurisdiction with drainage review authority, neighboring property owners, and residents about drainage problems;
- Note date and weather at time of inspection;

Task 4 – Describe the drainage system, and its existing and predicted problems.

For each drainage system component (e.g., pipe, culvert, bridges, outfalls, ponds, vaults) the following should be covered in the analysis: location, physical description, problems, and field observations. All existing or potential problems (e.g., ponding water, erosion) identified in Tasks 2 and 3 above should be described. The descriptions should be used to determine whether adequate mitigation can be identified, or whether more detailed quantitative analysis is necessary. The following information should be provided for each existing or potential problem:

- Magnitude of or damage caused by the problem;
- General frequency and duration;
- Return frequency of storm or flow when the problem occurs (may require quantitative analysis);
- Water elevation when the problem occurs;
- Names and concerns of parties involved;
- Current mitigation of the problem;
- Possible cause of the problem;
- Whether the project is likely to aggravate the problem or create a new one.

Upon review of this analysis, the local government may require mitigation measures to address the problems, or a quantitative analysis, depending upon the presence of existing or predicted flooding, erosion, or water quality problems, and on the proposed design of the on-site drainage facilities. The analysis should repeat Tasks 3 and 4 above, using quantitative field data including profiles and cross-sections.

The quantitative analysis should provide information on the severity and frequency of an existing problem or the likelihood of creating a new problem. It should evaluate proposed mitigation intended to avoid aggravation of the existing problem and to avoid creation of a new problem.

Appendix 3B – Basin Maps

PROJECT: ____

LOCATION: ____

DESIGNER: _____________________________ **COMPANY:** _______________________

DATE: __________________________________

The following items should be included on pre-developed and post-developed basin maps:

- ☐ Site boundary
- ☐ Basin limits, both on-site and off-site areas which contribute or receive stormwater runoff onto or from the project, field verified by the engineer.
- ☐ Drainage sub-basins. All sub-basins should be clearly labeled and correlated with the calculations.
- ☐ Topographic contours, which should extend beyond the project or drainage basin boundaries to the extent necessary to confirm basin limits used in the calculations; or, in the absence of topographic mapping being available, the Engineer may field verify the basin limits, including contributing off-site areas, and should describe how the basin limits were determined.
- ☐ Significant drainage features, natural or man-made, such as creeks, seasonal drainage channels, culverts, closed depressions, manholes.
- ☐ Time of concentration routes, clearly labeled and correlated with the calculations.
- ☐ Footprint of proposed drainage features, such as ponds, vegetated or other infiltration facilities, pipe routes, ditches.
- ☐ Indications of floodplain limits, as defined by FEMA or other studies.
- ☐ North arrow and scale bar.
- ☐ Wetlands
- ☐ Existing easements

Appendix 3C – Stormwater Construction Plans

PROJECT: ____

LOCATION: ____

DESIGNER: ____________________________ **COMPANY:** _______________________

DATE: _________________________________

The following items should be included on stormwater construction plans, as applicable:

- ☐ A plan profile of all key drainage systems including: streets, roads, and drainage facilities
- ☐ Elevation Datum
- ☐ North Arrow
- ☐ Right-of-Way details
- ☐ Outfall details
- ☐ Ditch details
- ☐ Invert elevations, slopes, and lengths of ditches
- ☐ Cross sections of all open ditches
- ☐ Elevations of all inlet grates
- ☐ Size, types, invert elevations, and lengths of all culverts and pipe systems
- ☐ Invert elevations of the existing or other proposed drainage system to which the drainage plan proposes to connect
- ☐ Stationing of all inlets, culverts and pipe systems angle points
- ☐ Invert elevations of pipes at all structures such as catch basins or manholes
- ☐ Construction details for inlets, drywells, detention facilities, etc. (notes referring to standard plans may suffice where applicable)
- ☐ Drainage easements shown, with key dimensions for depicting location, width, and length.
- ☐ The location of existing underground and above-ground utilities
- ☐ Lot grading elevations where appropriate
- ☐ Grading plan for drainage ponds. The grading plan should include existing contours, proposed contours, and catch points. A typical cross section of the pond should be provided in the plans, showing bottom of pond elevation, maximum water surface elevation for the design storm(s), inlet and outlet elevations, berm elevation and slopes, and keyway location and dimensions.

☐ Drainage ponds, pipe inlets and outlets, ditches, and drainage structures, which are serving public roads or are in single-family residential neighborhoods, should be horizontally defined with respect to property corners, street stationing, or a coordinate system.

☐ Drainage ditches should have their longitudinal grades defined with either a profile or elevation grades at intervals of 50 feet. Ditch centerlines and flow directions should be also be illustrated.

☐ Summary of short and long-term operation and maintenance requirements

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Chapter 4 - Hydrologic Analysis and Design

4.1 Introduction

4.1.1 Purpose

The purpose of this chapter is to provide guidance for sizing runoff treatment facilities to protect the quality of receiving waters and flow control facilities for protection of stream morphology and habitat.

The chapter does *not* provide guidance for sizing flood control facilities, conveyance systems, or subsurface infiltration facilities (drywells), but these methods may be used for design of those and other stormwater infrastructure components. Contact the local jurisdiction regarding design criteria and requirements.

In the general design of flow control facilities, the optimal placement of multiple small-scale retention/infiltration facilities within a drainage area may require less total storage capacity to meet a given peak flow rate target than a single large facility at the drainage area outlet. Application of low impact development (LID) techniques may also result in decreased storage requirements; see the discussion in Chapter 2.2.6, Supplemental Guidelines.

4.1.2 Hydrologic Analysis Methods and Applicability

One or more of the following modeling methods may be approved to analyze stormwater runoff from projects for design of **runoff treatment facilities** in a jurisdiction:

- Single event hydrograph methods:
  Soil Conservation Service (SCS) Hydrograph and
  Santa Barbara Urban Hydrograph (SBUH)
- Soil Conservation Service (SCS) Curve Number Equations
- Level-Pool Routing
- Rational Method

Flow control facilities must be sized using a single event hydrograph method and level-pool routing. If available and approved, a continuous runoff model or other hydrograph modeling method may be used.

Table 4.1.1 summarizes the situations in which each of the above methods may be used. Sections 4.4 through 4.7 describe their use in greater detail.

Other hydrograph models based on peer-reviewed methods and supported by local data also may be approved by agencies or local jurisdictions; some may require special expertise and experience in their application.

Table 4.1.1 Applicability of hydrologic analysis methods for runoff treatment and flow control facility design

Method	Application and Technology Requirements
Single event hydrograph methods: Soil Conservation Service (SCS) Hydrograph *or* Santa Barbara Urban Hydrograph (SBUH)	• Allowable method for computing peak runoff rates and runoff volumes for design of runoff treatment BMPs. • Required method for design of flow control BMPs. • Requires precipitation depth and distribution. • Computer is recommended due to intensive nature of calculations. • Some SCS hydrograph models such as TR-55 are restricted to 24-hour hyetographs and will not allow the regional and short-duration storm hyetographs developed for Eastern Washington.
Soil Conservation Service (SCS) Curve Number Equations	• Allowable method for computing volumes for water quality facilities based on SCS Hydrograph method. • Requires only precipitation depth. • Can be determined using a calculator.
Level-Pool Reservoir Routing	• Required method for routing hydrograph and determining size of flow control BMPs. • Requires precipitation depth and distribution. • Input may be SCS or SBUH hydrographs. • Computer is recommended due to intensive nature of calculations.
Rational Method	• Allowable method for computing peak runoff rates for flow based water quality BMPs such as biofiltration swales and oil/water separators. • Common method for calculating peak flows for the design of drywells and conveyance systems. • Requires only precipitation depth. • Can be determined using a calculator or spreadsheet program.
Other rainfall-runoff models that generate a hydrograph	• Other models can be used if approved by the local jurisdiction and the model meets the intent of Core Element 5 and(or) Core Element 6. • Requires precipitation depth and distribution. • Computer is recommended for most models due to intensive nature of calculations.

4.1.3 Hydrologic Analysis for Core Element #5 Runoff Treatment

Runoff treatment BMPs are utilized to treat the stormwater runoff from pollutant generating surfaces. Each treatment BMP is sized based on a water quality design volume, or a water quality design flow rate. Core Element #5 Runoff Treatment in Chapter 2 identifies the design volume or flow rate that needs to be treated. Agencies and local jurisdictions should adopt criteria to provide for consistent sizing of treatment facilities (see “Treatment Facility Sizing” in section 2.2.5). Various modeling approaches can be used to determine design and sizing requirements for runoff treatment facilities; the recommended methods for predicting runoff volumes and flow rates are included in this chapter. Specific design criteria for treatment facilities also may be identified in Chapter 5 in order to achieve the performance goal of a particular BMP.

4.1.4 Hydrologic Analysis for Core Element #6 Flow Control

Flow control facilities are intended to protect stream morphology and habitat; flood control and conveyance are not addressed. Core Element #6 Flow Control in Chapter 2 identifies the requirements for hydrologic analysis when designing flow control facilities to protect stream morphology and habitat. Core Element #6 also lists projects and locations that are exempt from the flow control requirement. In order to design a flow control facility, a hydrograph model must be used to compare the pre-developed or existing condition to the proposed-development condition. An agency or local jurisdiction may impose pre-determined or other more strict pre-developed or existing condition parameters. The suggested hydrograph method is a Single Event Hydrograph such as SCS or SBUH method; agencies or local jurisdictions may adopt other methods to meet the intent of the flow control requirement and(or) they may also require more stringent design criteria. The Curve Number method may *not* be used to design flow control facilities.

4.2 Design Storm Distributions

The design storms to be used in eastern Washington specify:

- Total rainfall volume (depth in inches), and
- Rainfall distribution (dimensionless).

The following sections explain total rainfall depth and rainfall distribution associated with a design storm. The design storm event is also specified by return period (months and/or years) and duration.

All rainfall-runoff hydrograph methods require the input of a rainfall distribution or design storm hyetograph. The hyetograph represents the portion of the total rainfall depth that falls during each increment of time for a given overall duration. It is usually presented as a dimensionless plot or table of unit rainfall depth (incremental rainfall depth for each time interval divided by the total rainfall depth) versus time.

These are the design storm distribution or rainfall depth options and the design problems for which they may be applied:

1. The 3-hour **short-duration storm** distribution, for design of flow-rate-based treatment BMPs.
2. The 24-hour or longer **regional storm** distribution (based on the 72-hour long-duration storm for each region), for design of flow control facilities and volume-based treatment BMPs.
3. The 24-hour **SCS Type IA storm** distribution, for design of flow control facilities in Regions 2 & 3 and volume-based treatment BMPs.

4. The **modified 24-hour SCS Type IA storm** distribution, for design of flow control facilities at small (less than one acre) projects in Regions 1 & 4 and volume-based treatment BMPs.
5. The 24-hour **SCS Type II storm** distribution, for design of volume-based and flow-rate-based treatment BMPs.
6. **One-half inch of runoff** from the site, depth only, no distribution; to be used only for determining runoff treatment volumes and only for projects located in Regions 2 & 3.
7. The **2-year mean precipitation depth** (no distribution), to be used only for determining peak flow rate by the Rational Method in designing flow-rate-based treatment BMPs.
8. **Other design criteria** adopted by agencies or local jurisdictions that meet or exceed the intent of the Core Elements for Runoff Treatment and Flow Control.

Options 1 through 5 are discussed in further detail in the following three sections. Tabular values for the hyetographs associated with these storms are provided in tables 4.2.2 through 4.2.8 at the end of the sections.

4.2.1 Short-Duration and Regional Design Storms

Rainfall patterns during storms in eastern Washington were analyzed to identify short-duration and regional rainfall distributions for regions of eastern Washington (see Appendix 4A). Two main storm types are of interest to hydrologic analysis for design of stormwater facilities in eastern Washington: the thunderstorms and general storms. The former is represented by the **short-duration storm** distribution and the latter is represented by the **regional storm** distribution. These design storms were developed in a manner that replicated temporal characteristics observed in storms from climatologically similar areas in and near eastern Washington. See Appendix 4A for further discussion of the development and review of these design storms. Appendix 4A.2 includes a graphical representation of the standard SCS Type IA and II synthetic design storms and the long-duration storms for comparison on a unit basis.

Thunderstorms can occur in the late spring through early-fall seasons and are characterized by high intensities for short periods of time over localized areas. These types of storms can produce high rates of runoff and flash flooding in urban areas and are important where flood peak discharge and/or erosion are design considerations. The effect of these storms should also be considered in designing facilities based on other design storms.

General storms can occur at anytime of the year, but are more common in the late fall through winter period, and in the late spring and early summer periods. General storms in eastern Washington are characterized by sequences of storms and intervening dry periods, often occurring over several days. Low to moderate intensity precipitation is typical during the periods of storm activity. These types of events can produce floods with moderate peak discharge and large runoff volumes. The runoff volume can be augmented by snowmelt when precipitation falls on snow during winter and early spring storms. These types of storm events are important where both runoff volume and peak discharge are design considerations.

Thunderstorms typically generate the greatest peak discharges for small urban watersheds. Use of short-duration storms is appropriate for design of conveyance structures and flow-rate-based treatment facilities including biofiltration swales.

General storms typically generate the greatest runoff volume. Use of the regional design storms is appropriate for design of stormwater detention and water quality treatment facilities where total runoff volume is the primary concern, and for flow control facilities where both the quantity and timing of runoff are of concern.

When utilizing these design storms, note that eastern Washington has been divided into four climatic regions to reflect the differences in storm characteristics and the seasonality of storms (see Figure 4.3.1). The four climatic regions are:

- **Region 1 – East Slopes of Cascade Mountains:** this region is comprised of mountain areas on the east slopes of the Cascade Mountains. It is bounded to the west by the Cascade crest and generally bounded to the east by the contour line of 16-inches average annual precipitation.
- **Region 2 – Central Basin:** this region is comprised of the Columbia Basin and adjacent low elevation areas in central Washington. It is generally bounded to the west by the contour line of 16-inches average annual precipitation at the base of the east slopes of the Cascade Mountains. The region is bounded to the north and east by the contour line of 14-inches average annual precipitation. The majority of the area in this region receives about eight inches of average annual precipitation. Many of the larger cities in eastern Washington are in this region including: Ellensburg, Kennewick, Moses Lake, Pasco, Richland, Wenatchee, and Yakima.
- **Region 3 – Okanogan, Spokane, Palouse:** this region is comprised of inter-mountain areas and includes areas near Okanogan, Spokane, and the Palouse. It is bounded to the northwest by the contour line of 16-inches average annual precipitation at the base of the east slopes of the Cascade Mountains. It is bounded to the south and west by the contour line of 12-inches average annual precipitation at the eastern edge of the Central Basin. It is bounded to the northeast by the Kettle River Range and Selkirk Mountains at approximately the contour line of 22-inches average annual

precipitation. It is bounded to the southeast by the Blue Mountains also at the contour line of 22-inches average annual precipitation.

- **Region 4 – Northeastern Mountains and Blue Mountains:** this region is comprised of mountain areas in the easternmost part of Washington State. It includes portions of the Kettle River Range and Selkirk Mountains in the northeast, and includes the Blue Mountains in the southeast corner of eastern Washington. Average annual precipitation ranges from a minimum of 22-inches to over 60-inches. The western boundary of this region is the contour line of 22-inches average annual precipitation.

Short-Duration Design Storm

Short durations, high intensity, and smaller volumes relative to general storms characterize summer thunderstorms. The short-duration storm hyetograph is 3 hours in duration. The storm temporal pattern is shown in Figure 4.2.1 as a unit hyetograph. Tabular values for this hyetograph are listed in Table 4.2.4. Total precipitation is 1.06 times the 2-hour precipitation amount. There is one short-duration storm for all climate regions in eastern Washington.

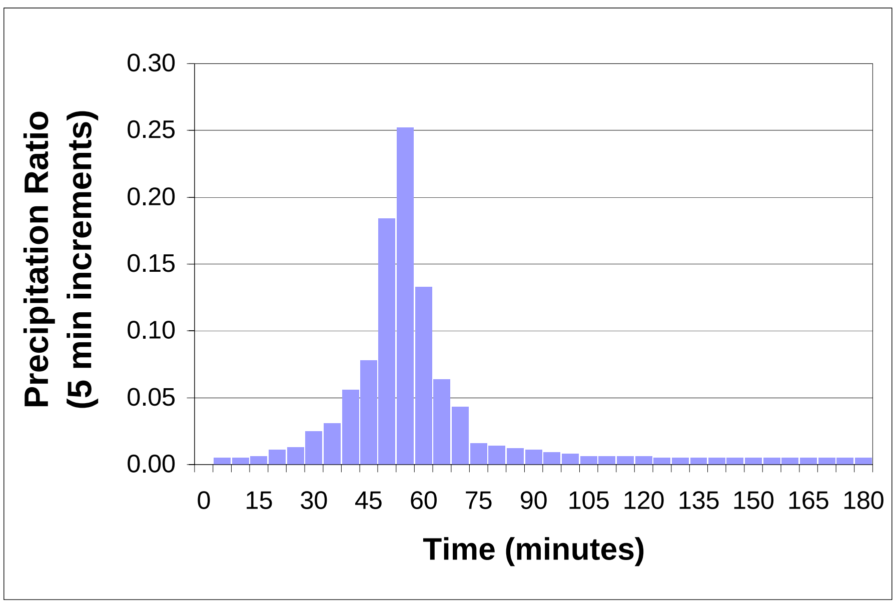


Figure 4.2.1 Short-duration storm unit hyetograph

Regional Storm

The general storm is characterized by lower rainfall intensities and larger volumes in a pattern that varies by region. The synthetic distribution represents a series of two rainfall events separated by a dry intervening period and occurring during a total 72-hour period of time. A sample 72-hour long-duration storm hyetograph is shown in Figure 4.2.2.

The regional storms are derived from these hyetographs (see Appendix 4A). The first, smaller precipitation event (occurring from 6 to 21 hours in Figure 4.2.2) is generally insufficient to generate runoff that is present when the larger second precipitation event commences and for that reason it is deemed unnecessary to directly model the smaller precipitation event and only the second, larger portion (beginning at 36 hours in Figure 4.2.2) is directly modeled. However, the soil wetting produced by the first event must still be accounted for by appropriately adjusting the modeling input parameters.

Tabular values of the regional storm hyetographs are listed in Tables 4.2.5 through 4.2.8. The regional storms are similar to the 24-hour SCS Type IA storm distribution. An adapted version of applying the Type IA distribution is discussed in section 4.2.3. Comparison of precipitation depths, antecedent moisture conditions, and necessary adjustments and modeling requirements for the regional storms are discussed in the section on the Modified SCS Type IA design storm, section 4.2.3.

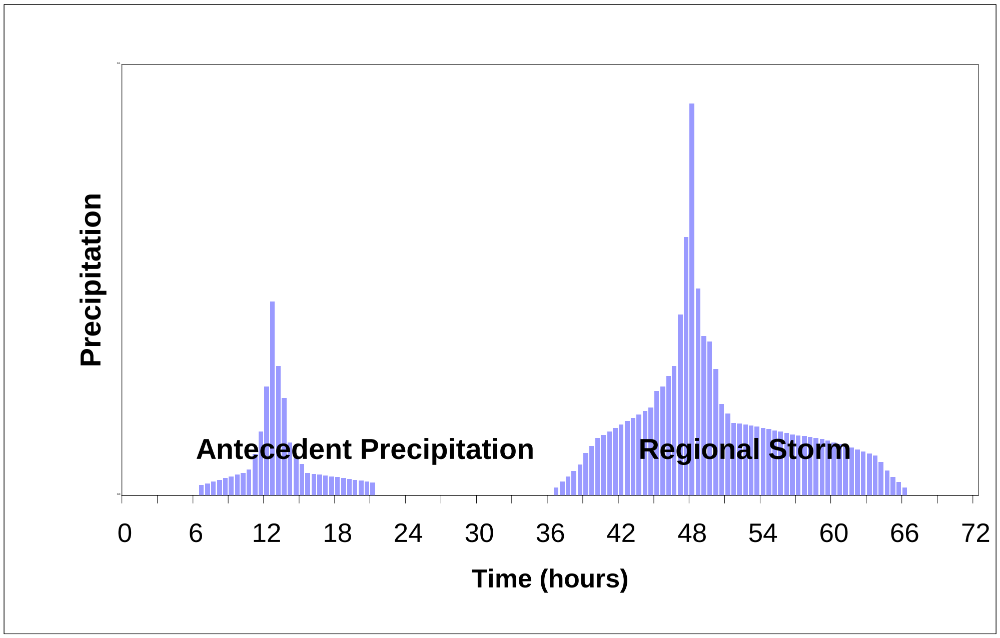


Figure 4.2.2 Sample regional storm hyetograph. The regional storm utilizes only the second event of the "long-duration storm" hyetograph, following the dry period and beginning at about 36 hours.

4.2.2 SCS Type II and Type IA Standard Design Storms

Note: *the U.S. Soil Conservation Service (SCS) is now known as the Natural Resources Conservation Service, or NRCS.*

These are two of the four standard 24-hour rainfall distributions that are commonly used in SCS hydrograph methods.

The **SCS Type II** hyetograph has a high intensity peak. It has been utilized in eastern Washington since the 1970s and is also used throughout much of the United States. The SCS Type II standard rainfall distribution does not match historical records for the two main storm types of interest to hydrologic analysis for design of stormwater facilities in eastern Washington: the short-duration thunderstorm and the long-duration general storm.

The **SCS Type IA** hyetograph has lower rainfall intensities and was originally identified by SCS as applicable to western Washington and the eastern slopes of the Cascade Mountains. The SCS Type IA storm is similar to the four regional storms and recent analysis supports the direct application of this hyetograph throughout eastern Washington; see Appendix 4A.2. The following section describes a modified application that incorporates information from the historical analysis.

See Figures 4.2.3 and 4.2.4 for graphical representations of these two SCS hyetographs. Tabular values of these hyetographs are in Tables 4.2.2 and 4.2.3. See Appendix 4A.2 for a graphical representation of these two storms and the long-duration storms for comparison on a unit basis.

4.2.3 Modified SCS Type IA and Regional Design Storms

The modified SCS Type IA design storm is an adapted application of the standard SCS Type IA design storm intended to more closely reflect historical precipitation patterns in eastern Washington. Antecedent moisture conditions and precipitation depths are modified to reflect more typical conditions.

Various agencies and local jurisdictions may choose to implement either the regional design storms (discussed in section 4.2.1) or the SCS Type IA design storm. Since the regional storms have more total precipitation but are spread over more time than the 24-hour SCS Type IA, the computed peak flows and volumes tend to be reasonably similar. For Region 2, there are no measurable differences in precipitation total or duration. For Regions 3 and 4, the differences in rainfall depth are minor: total precipitation is no more than 7% greater than the standard 24-hour SCS Type IA storm; the durations are several hours longer. For Region 1, the differences are greatest: a 16% increase in precipitation depth compared to the 24-hour SCS Type IA storm, and more than 40% longer duration.

If the 24-hour SCS Type IA storm is used directly, the precipitation totals are the 24-hour amounts without adjustment. If the modified Type IA is used, the precipitation totals need to be adjusted as indicated in Table 4.2.10 in section 4.2.5; these adjustment factors are also in the notes in Tables 4.2.5 through 4.2.8.

The prior soil wetting produced by the previous storm event in the long-duration storm (the portion that is not included in the modeling exercise) still needs to be accounted for by appropriately adjusting the modeling input parameters. Regardless of whether the 24-hour SCS Type IA or regional storm hyetographs are used for modeling, this adjustment must be made. The amount of antecedent precipitation can be expressed as a percentage of the total precipitation modeled, as shown in Table 4.2.1.

Table 4.2.1 Antecedent precipitation prior to regional storm

Region #	Region Name	Antecedent precipitation as percentage of 24-hour SCS Type IA Storm precipitation
1	East Slope Cascades	33%
2	Central Basin	19%
3	Okanogan, Spokane, Palouse	27%
4	NE & Blue Mountains	36%

Region #	Region Name	Antecedent precipitation as percentage of regional long-duration storm hyetograph precipitation
1	East Slope Cascades	28%
2	Central Basin	19%
3	Okanogan, Spokane, Palouse	25%
4	NE & Blue Mountains	34%

Curve number adjustments based on engineering analysis and judgment of the antecedent precipitation, soils characteristics, and surface conditions must be considered. The Antecedent Moisture Condition discussion in this chapter (see section 4.5.3) is one basis for adjustment. Another is the use of the Soil Conservation Service county surveys that include estimates of permeability and/or infiltration rates.

Precipitation magnitudes and frequencies are adjusted as discussed in section 4.2.5.

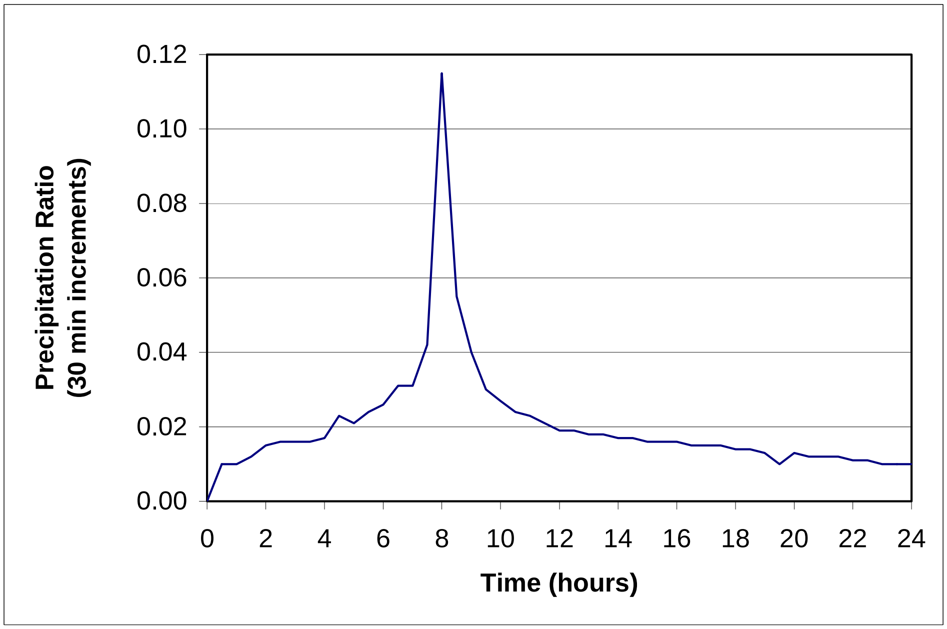


Figure 4.2.3 SCS Type IA Hyetograph

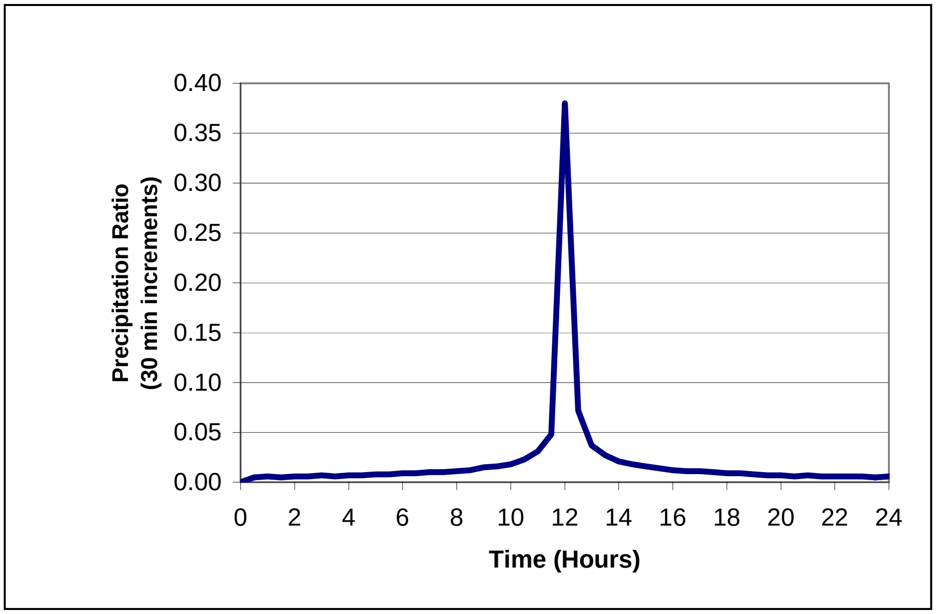


Figure 4.2.4 SCS Type II Hyetograph

Table 4.2.2 SCS Type IA Storm Hyetograph Values

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.000	0.000
0.1	0.002	0.002
0.2	0.002	0.004
0.3	0.002	0.006
0.4	0.002	0.008
0.5	0.002	0.010
0.6	0.002	0.012
0.7	0.002	0.014
0.8	0.002	0.016
0.9	0.002	0.018
1.0	0.002	0.020
1.1	0.003	0.023
1.2	0.003	0.026
1.3	0.003	0.029
1.4	0.003	0.032
1.5	0.003	0.035
1.6	0.003	0.038
1.7	0.003	0.041
1.8	0.003	0.044
1.9	0.003	0.047
2.0	0.003	0.050
2.1	0.003	0.053
2.2	0.003	0.056
2.3	0.004	0.060
2.4	0.003	0.063
2.5	0.003	0.066
2.6	0.003	0.069
2.7	0.003	0.072
2.8	0.004	0.076
2.9	0.003	0.079
3.0	0.003	0.082
3.1	0.003	0.085
3.2	0.003	0.088
3.3	0.003	0.091
3.4	0.004	0.095
3.5	0.003	0.098
3.6	0.003	0.101
3.7	0.004	0.105
3.8	0.004	0.109
3.9	0.003	0.112
4.0	0.004	0.116
4.1	0.004	0.120
4.2	0.003	0.123
4.3	0.004	0.127
4.4	0.004	0.131

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
4.5	0.004	0.135
4.6	0.004	0.139
4.7	0.004	0.143
4.8	0.004	0.147
4.9	0.005	0.152
5.0	0.004	0.156
5.1	0.005	0.161
5.2	0.004	0.165
5.3	0.005	0.170
5.4	0.005	0.175
5.5	0.005	0.180
5.6	0.005	0.185
5.7	0.005	0.190
5.8	0.005	0.195
5.9	0.005	0.200
6.0	0.006	0.206
6.1	0.006	0.212
6.2	0.006	0.218
6.3	0.006	0.224
6.4	0.007	0.231
6.5	0.006	0.237
6.6	0.006	0.243
6.7	0.006	0.249
6.8	0.006	0.255
6.9	0.006	0.261
7.0	0.007	0.268
7.1	0.007	0.275
7.2	0.008	0.283
7.3	0.008	0.291
7.4	0.009	0.300
7.5	0.010	0.310
7.6	0.021	0.331
7.7	0.024	0.355
7.8	0.024	0.379
7.9	0.024	0.403
8.0	0.022	0.425
8.1	0.014	0.439
8.2	0.013	0.452
8.3	0.010	0.462
8.4	0.010	0.472
8.5	0.008	0.480
8.6	0.009	0.489
8.7	0.009	0.498
8.8	0.007	0.505
8.9	0.008	0.513

Time (0.1 hours)	Incrementa l Rainfall	Cumulative Rainfall
9.0	0.007	0.520
9.1	0.007	0.527
9.2	0.006	0.533
9.3	0.006	0.539
9.4	0.006	0.545
9.5	0.005	0.550
9.6	0.006	0.556
9.7	0.005	0.561
9.8	0.006	0.567
9.9	0.005	0.572
10.0	0.005	0.577
10.1	0.005	0.582
10.2	0.005	0.587
10.3	0.005	0.592
10.4	0.004	0.596
10.5	0.005	0.601
10.6	0.005	0.606
10.7	0.004	0.610
10.8	0.005	0.615
10.9	0.005	0.620
11.0	0.004	0.624
11.1	0.004	0.628
11.2	0.005	0.633
11.3	0.004	0.637
11.4	0.004	0.641
11.5	0.004	0.645
11.6	0.004	0.649
11.7	0.004	0.653
11.8	0.004	0.657
11.9	0.003	0.660
12.0	0.004	0.664
12.1	0.004	0.668
12.2	0.003	0.671
12.3	0.004	0.675
12.4	0.004	0.679
12.5	0.004	0.683
12.6	0.004	0.687
12.7	0.003	0.690
12.8	0.004	0.694
12.9	0.003	0.697
13.0	0.004	0.701
13.1	0.004	0.705
13.2	0.003	0.708
13.3	0.004	0.712
13.4	0.004	0.716

Table 4.2.2 (continued) SCS Type IA Storm Hyetograph Values

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
13.5	0.003	0.719
13.6	0.003	0.722
13.7	0.004	0.726
13.8	0.003	0.729
13.9	0.004	0.733
14.0	0.003	0.736
14.1	0.003	0.739
14.2	0.004	0.743
14.3	0.003	0.746
14.4	0.003	0.749
14.5	0.004	0.753
14.6	0.003	0.756
14.7	0.003	0.759
14.8	0.004	0.763
14.9	0.003	0.766
15.0	0.003	0.769
15.1	0.003	0.772
15.2	0.004	0.776
15.3	0.003	0.779
15.4	0.003	0.782
15.5	0.003	0.785
15.6	0.003	0.788
15.7	0.004	0.792
15.8	0.003	0.795
15.9	0.003	0.798
16.0	0.003	0.801
16.1	0.003	0.804
16.2	0.003	0.807
16.3	0.003	0.810
16.4	0.003	0.813
16.5	0.003	0.816
16.6	0.003	0.819
16.7	0.003	0.822
16.8	0.003	0.825
16.9	0.003	0.828
17.0	0.003	0.831
17.1	0.003	0.834
17.2	0.003	0.837
17.3	0.003	0.840
17.4	0.003	0.843
17.5	0.003	0.846
17.6	0.003	0.849
17.7	0.002	0.851
17.8	0.003	0.854
17.9	0.003	0.857

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
18.0	0.003	0.860
18.1	0.003	0.863
18.2	0.002	0.865
18.3	0.003	0.868
18.4	0.003	0.871
18.5	0.003	0.874
18.6	0.002	0.876
18.7	0.003	0.879
18.8	0.003	0.882
18.9	0.002	0.884
19.0	0.003	0.887
19.1	0.003	0.890
19.2	0.002	0.892
19.3	0.003	0.895
19.4	0.002	0.897
19.5	0.003	0.900
19.6	0.003	0.903
19.7	0.002	0.905
19.8	0.003	0.908
19.9	0.002	0.910
20.0	0.003	0.913
20.1	0.002	0.915
20.2	0.003	0.918
20.3	0.002	0.920
20.4	0.002	0.922
20.5	0.003	0.925
20.6	0.002	0.927
20.7	0.003	0.930
20.8	0.002	0.932
20.9	0.002	0.934
21.0	0.003	0.937
21.1	0.002	0.939
21.2	0.002	0.941
21.3	0.003	0.944
21.4	0.002	0.946
21.5	0.002	0.948
21.6	0.003	0.951
21.7	0.002	0.953
21.8	0.002	0.955
21.9	0.002	0.957
22.0	0.002	0.959
22.1	0.003	0.962
22.2	0.002	0.964
22.3	0.002	0.966
22.4	0.002	0.968

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
22.5	0.002	0.970
22.6	0.002	0.972
22.7	0.002	0.974
22.8	0.002	0.976
22.9	0.002	0.978
23.0	0.002	0.980
23.1	0.002	0.982
23.2	0.002	0.984
23.3	0.002	0.986
23.4	0.002	0.988
23.5	0.002	0.990
23.6	0.002	0.992
23.7	0.002	0.994
23.8	0.002	0.996
23.9	0.002	0.998
24.0	0.002	1.000

Table 4.2.3 SCS Type II Storm Hyetograph Values

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.000	0.000
0.1	0.001	0.001
0.2	0.001	0.002
0.3	0.001	0.003
0.4	0.001	0.004
0.5	0.001	0.005
0.6	0.001	0.006
0.7	0.001	0.007
0.8	0.001	0.008
0.9	0.001	0.009
1.0	0.002	0.011
1.1	0.001	0.012
1.2	0.001	0.013
1.3	0.001	0.014
1.4	0.001	0.015
1.5	0.001	0.016
1.6	0.001	0.017
1.7	0.001	0.018
1.8	0.002	0.020
1.9	0.001	0.021
2.0	0.001	0.022
2.1	0.001	0.023
2.2	0.001	0.024
2.3	0.002	0.026
2.4	0.001	0.027
2.5	0.001	0.028
2.6	0.001	0.029
2.7	0.002	0.031
2.8	0.001	0.032
2.9	0.001	0.033
3.0	0.002	0.035
3.1	0.001	0.036
3.2	0.001	0.037
3.3	0.001	0.038
3.4	0.002	0.040
3.5	0.001	0.041
3.6	0.001	0.042
3.7	0.002	0.044
3.8	0.001	0.045
3.9	0.002	0.047
4.0	0.001	0.048
4.1	0.001	0.049
4.2	0.002	0.051
4.3	0.001	0.052
4.4	0.002	0.054

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
4.5	0.001	0.055
4.6	0.002	0.057
4.7	0.001	0.058
4.8	0.002	0.060
4.9	0.001	0.061
5.0	0.002	0.063
5.1	0.002	0.065
5.2	0.001	0.066
5.3	0.002	0.068
5.4	0.002	0.070
5.5	0.001	0.071
5.6	0.002	0.073
5.7	0.002	0.075
5.8	0.001	0.076
5.9	0.002	0.078
6.0	0.002	0.080
6.1	0.002	0.082
6.2	0.002	0.084
6.3	0.001	0.085
6.4	0.002	0.087
6.5	0.002	0.089
6.6	0.002	0.091
6.7	0.002	0.093
6.8	0.002	0.095
6.9	0.002	0.097
7.0	0.002	0.099
7.1	0.002	0.101
7.2	0.002	0.103
7.3	0.002	0.105
7.4	0.002	0.107
7.5	0.002	0.109
7.6	0.002	0.111
7.7	0.002	0.113
7.8	0.003	0.116
7.9	0.002	0.118
8.0	0.002	0.120
8.1	0.002	0.122
8.2	0.003	0.125
8.3	0.002	0.127
8.4	0.003	0.130
8.5	0.002	0.132
8.6	0.003	0.135
8.7	0.003	0.138
8.8	0.003	0.141
8.9	0.003	0.144

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
9.0	0.003	0.147
9.1	0.003	0.150
9.2	0.003	0.153
9.3	0.004	0.157
9.4	0.003	0.160
9.5	0.003	0.163
9.6	0.003	0.166
9.7	0.004	0.170
9.8	0.003	0.173
9.9	0.004	0.177
10.0	0.004	0.181
10.1	0.004	0.185
10.2	0.004	0.189
10.3	0.005	0.194
10.4	0.005	0.199
10.5	0.005	0.204
10.6	0.005	0.209
10.7	0.006	0.215
10.8	0.006	0.221
10.9	0.007	0.228
11.0	0.007	0.235
11.1	0.008	0.243
11.2	0.008	0.251
11.3	0.010	0.261
11.4	0.010	0.271
11.5	0.012	0.283
11.6	0.024	0.307
11.7	0.047	0.354
11.8	0.077	0.431
11.9	0.137	0.568
12.0	0.095	0.663
12.1	0.019	0.682
12.2	0.017	0.699
12.3	0.014	0.713
12.4	0.012	0.725
12.5	0.010	0.735
12.6	0.008	0.743
12.7	0.008	0.751
12.8	0.008	0.759
12.9	0.007	0.766
13.0	0.006	0.772
13.1	0.006	0.778
13.2	0.006	0.784
13.3	0.005	0.789
13.4	0.005	0.794

Table 4.2.3 (continued) SCS Type II Storm Hyetograph Values

Time (0.1 hours)	Incremental Rainfall	Cumulative Rainfall
13.5	0.005	0.799
13.6	0.005	0.804
13.7	0.004	0.808
13.8	0.004	0.812
13.9	0.004	0.816
14.0	0.004	0.820
14.1	0.004	0.824
14.2	0.003	0.827
14.3	0.004	0.831
14.4	0.003	0.834
14.5	0.004	0.838
14.6	0.003	0.841
14.7	0.003	0.844
14.8	0.003	0.847
14.9	0.003	0.850
15.0	0.004	0.854
15.1	0.002	0.856
15.2	0.003	0.859
15.3	0.003	0.862
15.4	0.003	0.865
15.5	0.003	0.868
15.6	0.002	0.870
15.7	0.003	0.873
15.8	0.002	0.875
15.9	0.003	0.878
16.0	0.002	0.880
16.1	0.002	0.882
16.2	0.003	0.885
16.3	0.002	0.887
16.4	0.002	0.889
16.5	0.002	0.891
16.6	0.002	0.893
16.7	0.002	0.895
16.8	0.003	0.898
16.9	0.002	0.900
17.0	0.002	0.902
17.1	0.002	0.904
17.2	0.002	0.906
17.3	0.002	0.908
17.4	0.002	0.910
17.5	0.002	0.912
17.6	0.002	0.914
17.7	0.001	0.915
17.8	0.002	0.917
17.9	0.002	0.919
18.0	0.002	0.921
18.1	0.002	0.923
18.2	0.002	0.925
18.3	0.001	0.926
18.4	0.002	0.928
18.5	0.002	0.930
18.6	0.001	0.931
18.7	0.002	0.933
18.8	0.002	0.935
18.9	0.001	0.936
19.0	0.002	0.938
19.1	0.001	0.939
19.2	0.002	0.941
19.3	0.001	0.942
19.4	0.002	0.944
19.5	0.001	0.945
19.6	0.002	0.947
19.7	0.001	0.948
19.8	0.001	0.949
19.9	0.002	0.951
20.0	0.001	0.952
20.1	0.001	0.953
20.2	0.002	0.955
20.3	0.001	0.956
20.4	0.001	0.957
20.5	0.001	0.958
20.6	0.002	0.960
20.7	0.001	0.961
20.8	0.001	0.962
20.9	0.002	0.964
21.0	0.001	0.965
21.1	0.001	0.966
21.2	0.001	0.967
21.3	0.001	0.968
21.4	0.002	0.970
21.5	0.001	0.971
21.6	0.001	0.972
21.7	0.001	0.973
21.8	0.002	0.975
21.9	0.001	0.976
22.0	0.001	0.977
22.1	0.001	0.978
22.2	0.001	0.979
22.3	0.002	0.981
22.4	0.001	0.982
22.5	0.001	0.983
22.6	0.001	0.984
22.7	0.001	0.985
22.8	0.001	0.986
22.9	0.002	0.988
23.0	0.001	0.989
23.1	0.001	0.990
23.2	0.001	0.991
23.3	0.001	0.992
23.4	0.001	0.993
23.5	0.001	0.994
23.6	0.002	0.996
23.7	0.001	0.997
23.8	0.001	0.998
23.9	0.001	0.999
24.0	0.001	1.000

Table 4.2.4 Short-Duration Storm Hyetograph Values for All Regions

Note: Use the 2-hour precipitation value times 1.06 to determine the 3-hour total precipitation amount.

Time (minutes)	Time (hours)	Incremental Rainfall	Cumulative Rainfall
0	0	0.0000	0.0000
5	0.08	0.0047	0.0047
10	0.17	0.0047	0.0094
15	0.25	0.0057	0.0151
20	0.33	0.0104	0.0255
25	0.42	0.0123	0.0378
30	0.50	0.0236	0.0614
35	0.58	0.0292	0.0906
40	0.67	0.0528	0.1434
45	0.75	0.0736	0.2170
50	0.83	0.1736	0.3906
55	0.92	0.2377	0.6283
60	1.00	0.1255	0.7538
65	1.08	0.0604	0.8142
70	1.17	0.0406	0.8548
75	1.25	0.0151	0.8699
80	1.33	0.0132	0.8831
85	1.42	0.0113	0.8944
90	1.50	0.0104	0.9048
95	1.58	0.0085	0.9133
100	1.67	0.0075	0.9208
105	1.75	0.0057	0.9265
110	1.83	0.0057	0.9322
115	1.92	0.0057	0.9379
120	2.00	0.0057	0.9436
125	2.08	0.0047	0.9483
130	2.17	0.0047	0.9530
135	2.25	0.0047	0.9577
140	2.33	0.0047	0.9624
145	2.42	0.0047	0.9671
150	2.50	0.0047	0.9718
155	2.58	0.0047	0.9765
160	2.67	0.0047	0.9812
165	2.75	0.0047	0.9859
170	2.83	0.0047	0.9906
175	2.92	0.0047	0.9953
180	3.00	0.0047	1.0000

Table 4.2.5 Regional Storm Hyetograph Values for Region 1: Cascade Mountains

Note: Use the 24-hour precipitation value times 1.16 to determine the long-duration storm total precipitation amount.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000
0.5	0.0024	0.0024
1.0	0.0036	0.0060
1.5	0.0040	0.0101
2.0	0.0047	0.0148
2.5	0.0051	0.0199
3.0	0.0054	0.0253
3.5	0.0058	0.0311
4.0	0.0062	0.0374
4.5	0.0066	0.0439
5.0	0.0078	0.0517
5.5	0.0096	0.0614
6.0	0.0120	0.0733
6.5	0.0138	0.0871
7.0	0.0150	0.1022
7.5	0.0157	0.1179
8.0	0.0164	0.1343
8.5	0.0171	0.1513
9.0	0.0178	0.1691
9.5	0.0185	0.1876
10.0	0.0192	0.2067
10.5	0.0198	0.2266
11.0	0.0205	0.2471
11.5	0.0212	0.2683
12.0	0.0220	0.2904

Time (hours)	Incremental Rainfall	Cumulative Rainfall
12.5	0.0226	0.3130
13.0	0.0235	0.3364
13.5	0.0243	0.3608
14.0	0.0297	0.3905
14.5	0.0338	0.4243
15.0	0.0507	0.4750
15.5	0.0315	0.5066
16.0	0.0283	0.5349
16.5	0.0257	0.5606
17.0	0.0231	0.5837
17.5	0.0214	0.6051
18.0	0.0183	0.6234
18.5	0.0168	0.6402
19.0	0.0165	0.6566
19.5	0.0161	0.6728
20.0	0.0158	0.6886
20.5	0.0154	0.7040
21.0	0.0151	0.7191
21.5	0.0148	0.7339
22.0	0.0144	0.7483
22.5	0.0141	0.7623
23.0	0.0137	0.7761
23.5	0.0134	0.7894
24.0	0.0130	0.8025
24.5	0.0127	0.8151

Time (hours)	Incremental Rainfall	Cumulative Rainfall
25.0	0.0123	0.8275
25.5	0.0120	0.8395
26.0	0.0117	0.8512
26.5	0.0115	0.8627
27.0	0.0112	0.8739
27.5	0.0110	0.8849
28.0	0.0107	0.8956
28.5	0.0104	0.9060
29.0	0.0102	0.9162
29.5	0.0099	0.9261
30.0	0.0097	0.9358
30.5	0.0088	0.9446
31.0	0.0079	0.9525
31.5	0.0071	0.9596
32.0	0.0063	0.9659
32.5	0.0058	0.9717
33.0	0.0054	0.9772
33.5	0.0050	0.9822
34.0	0.0047	0.9869
34.5	0.0043	0.9912
35.0	0.0039	0.9950
35.5	0.0030	0.9981
36.0	0.0019	1.0000

Table 4.2.6 Regional Storm Hyetograph Values for Region 2: Central Basin

Note: Use the 24-hour precipitation value (times 1.00) to determine the long-duration storm total precipitation amount.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000
0.5	0.0054	0.0054
1.0	0.0086	0.0140
1.5	0.0100	0.0240
2.0	0.0120	0.0360
2.5	0.0130	0.0490
3.0	0.0140	0.0630
3.5	0.0150	0.0780
4.0	0.0160	0.0940
4.5	0.0170	0.1110
5.0	0.0187	0.1297
5.5	0.0228	0.1525
6.0	0.0283	0.1808
6.5	0.0305	0.2113
7.0	0.0335	0.2448
7.5	0.0365	0.2813
8.0	0.0484	0.3297
8.5	0.0622	0.3919
9.0	0.0933	0.4852
9.5	0.0527	0.5380
10.0	0.0402	0.5782
10.5	0.0372	0.6154
11.0	0.0348	0.6502
11.5	0.0331	0.6833
12.0	0.0289	0.7122
12.5	0.0252	0.7374
13.0	0.0219	0.7593
13.5	0.0191	0.7783
14.0	0.0167	0.7950
14.5	0.0148	0.8098
15.0	0.0134	0.8232
15.5	0.0123	0.8355
16.0	0.0116	0.8471
16.5	0.0110	0.8581
17.0	0.0105	0.8686
17.5	0.0103	0.8789
18.0	0.0103	0.8892
18.5	0.0104	0.8996
19.0	0.0105	0.9100
19.5	0.0105	0.9205
20.0	0.0104	0.9309
20.5	0.0102	0.9412
21.0	0.0100	0.9512
21.5	0.0097	0.9609
22.0	0.0093	0.9702
22.5	0.0087	0.9789
23.0	0.0083	0.9872
23.5	0.0078	0.9950
24.0	0.0050	1.0000

Table 4.2.7 Regional Storm Hyetograph Values for Region 3: Okanogan, Spokane, Palouse

Note: Use the 24-hour precipitation value times 1.06 to determine long-duration storm total precipitation amount.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000
0.5	0.0017	0.0017
1.0	0.0030	0.0047
1.5	0.0041	0.0088
2.0	0.0053	0.0141
2.5	0.0068	0.0209
3.0	0.0092	0.0301
3.5	0.0108	0.0409
4.0	0.0126	0.0535
4.5	0.0132	0.0667
5.0	0.0139	0.0806
5.5	0.0147	0.0952
6.0	0.0154	0.1106
6.5	0.0162	0.1268
7.0	0.0169	0.1437
7.5	0.0177	0.1614
8.0	0.0184	0.1798
8.5	0.0192	0.1990
9.0	0.0228	0.2219
9.5	0.0238	0.2457
10.0	0.0260	0.2717
10.5	0.0282	0.2999
11.0	0.0395	0.3394
11.5	0.0564	0.3958
12.0	0.0855	0.4813
12.5	0.0451	0.5265
13.0	0.0348	0.5612
13.5	0.0335	0.5948
14.0	0.0276	0.6223
14.5	0.0199	0.6422
15.0	0.0179	0.6601
15.5	0.0158	0.6759
16.0	0.0156	0.6915
16.5	0.0154	0.7069
17.0	0.0152	0.7221
17.5	0.0150	0.7372
18.0	0.0148	0.7519
18.5	0.0145	0.7664
19.0	0.0142	0.7806
19.5	0.0139	0.7945
20.0	0.0136	0.8081
20.5	0.0133	0.8215
21.0	0.0131	0.8346
21.5	0.0130	0.8475
22.0	0.0128	0.8603
22.5	0.0126	0.8729
23.0	0.0123	0.8852
23.5	0.0120	0.8972
24.0	0.0116	0.9088
24.5	0.0112	0.9200
25.0	0.0108	0.9308
25.5	0.0104	0.9412
26.0	0.0100	0.9512
26.5	0.0096	0.9607
27.0	0.0092	0.9699
27.5	0.0086	0.9785
28.0	0.0074	0.9859
28.5	0.0054	0.9913
29.0	0.0040	0.9953
29.5	0.0030	0.9983
30.0	0.0017	1.0000

Table 4.2.8 Regional Storm Hyetograph Values for Region 4: Eastern Mountains

Note: Use the 24-hour precipitation value times 1.07 to determine the long-duration storm total precipitation amount.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.0000	0.0000
0.5	0.0015	0.0015
1.0	0.0031	0.0046
1.5	0.0047	0.0094
2.0	0.0064	0.0158
2.5	0.0082	0.0239
3.0	0.0104	0.0343
3.5	0.0115	0.0458
4.0	0.0123	0.0581
4.5	0.0130	0.0711
5.0	0.0137	0.0848
5.5	0.0145	0.0993
6.0	0.0152	0.1145
6.5	0.0160	0.1305
7.0	0.0167	0.1472
7.5	0.0174	0.1646
8.0	0.0182	0.1828
8.5	0.0190	0.2019
9.0	0.0207	0.2226
9.5	0.0232	0.2458
10.0	0.0260	0.2717
10.5	0.0278	0.2996
11.0	0.0399	0.3394
11.5	0.0531	0.3925
12.0	0.0796	0.4722
12.5	0.0441	0.5162
13.0	0.0329	0.5492
13.5	0.0303	0.5795
14.0	0.0291	0.6086
14.5	0.0199	0.6284
15.0	0.0166	0.6451
15.5	0.0155	0.6606
16.0	0.0153	0.6759
16.5	0.0151	0.6910
17.0	0.0149	0.7059
17.5	0.0148	0.7207
18.0	0.0146	0.7353
18.5	0.0144	0.7496
19.0	0.0142	0.7639
19.5	0.0140	0.7779
20.0	0.0137	0.7915
20.5	0.0134	0.8049
21.0	0.0132	0.8181
21.5	0.0131	0.8312
22.0	0.0129	0.8441
22.5	0.0129	0.8570
23.0	0.0128	0.8697
23.5	0.0127	0.8825
24.0	0.0127	0.8951
24.5	0.0126	0.9077
25.0	0.0124	0.9201
25.5	0.0121	0.9322
26.0	0.0116	0.9438
26.5	0.0109	0.9547
27.0	0.0101	0.9647
27.5	0.0090	0.9738
28.0	0.0077	0.9814
28.5	0.0061	0.9875
29.0	0.0051	0.9926
29.5	0.0045	0.9971
30.0	0.0029	1.0000

4.2.4 Precipitation Magnitude/Frequency Analysis

The current source for precipitation magnitude-frequency estimates is NOAA Atlas II, which is based on data collected from about 1940 through 1966, and NOAA Technical Report Number 36, which used data through the late 1970s. In both of these studies, precipitation statistics were computed for each gage and used to produce point precipitation estimates at each site. The accuracy of the estimates was strongly related to the length of record at each site: estimates are generally better for common events than for rare events.

The total depth of rainfall (in tenths of an inch) for storms of 2, 5, 10, 25, 50, and 100-year recurrence intervals and 24-hour duration are published by NOAA in the form of isopluvial maps for each state. Isopluvial maps are contour maps where the contours represent total amount of rainfall. The maps for eastern Washington are shown in Figures 4.3.3 to 4.3.7; they are based on NOAA Atlas 2 maps, which are available on the Internet. The 24-hour isopluvial maps are used for designs based on the regional storm and 24-hour storms. A 2-year isopluvial map is necessary because a 6-month isopluvial map is not available. The user must scale the 2-year precipitation depth to get a 6-month precipitation depth.

An isopluvial map for the 2-year,2-hour storm is shown in Figure 4.3.2. This map is from the Dam Safety Guidelines, Technical Note 3, Design Storm Construction, Washington State Department of Ecology, Water Resources Program, report 92-55G, April 1993. It is used for sizing flow-rate-based runoff treatment BMPs with the short-duration storm.

4.2.5 Precipitation Magnitude and Frequency for 24-Hour and Regional Storms

The frequency of the water quality design storm is a 6-month recurrence interval or return period, expected to happen twice per year on the average. NOAA maps were not developed for the 6-month recurrence interval, so a conversion is necessary. Use the following equation to determine the 6-month precipitation from the 2-year,24-hour precipitation.

$$\mathbf{P_{wqs} = C_{wqs} (P_{2yr24hr})}$$

where: $\mathbf{P_{wqs}}$ = the 6-month,24-hour precipitation (inches)

$\mathbf{C_{wqs}}$ = the coefficient from Table 4.2.9 for converting the 2-year,24-hour precipitation to the 6-month,24-hour precipitation

$\mathbf{P_{2yr24hr}}$ = the 2-year,24-hour precipitation (inches), from Figure 4.3.3

P_{wqs} is used with the regional storm hyetograph or SCS Type IA or Type II hyetographs. Table 4.2.9 lists values of the coefficient C_{wqs} for the four climate regions. Table 4.2.10 provides the multipliers for converting the 24-hour precipitation P_{wqs} to the regional storm precipitation

Table 4.2.9 Values of coefficient C_{wqs} for computing 6-month, 24-hour precipitation.

Region #	Region Name	C_{wqs}
1	East Slope Cascades	0.70
2	Central Basin	0.66
3	Okanogan, Spokane, Palouse	0.69
4	NE & Blue Mountains	0.70

Note: Values of C_{wqs} are based on the Generalized Extreme Value (GEV) distribution whose distribution parameters can be expressed as a function of mean annual precipitation for eastern Washington.

Table 4.2.10 Factors for converting from 24-hour to regional storm precipitation depth

Region #	Region Name	Multiplication factor for converting from 24-hour to regional storm precipitation depth
1	East Slope Cascades	1.16
2	Central Basin	1.00
3	Okanogan, Spokane, Palouse	1.06
4	NE & Blue Mountains	1.07

4.2.6 Precipitation Magnitude and Frequency for Short-Duration Storms

Design of flow-rate-based treatment BMPs using the Single Event Hydrograph Model requires a determination of the 6-month,3-hour precipitation depth for use with the 3-hour short-duration design storm hyetograph. (The updated design storm is indexed to sum to unity at three hours, so the 3-hour precipitation depth is needed to scale the hyetograph.) Design of other BMPs or conveyance elements based on the short-duration storm may also require the conversion of the 2-year,2-hour precipitation to a 3-hour precipitation depth for a different recurrence interval.

The isopluvial map that is used as the starting point for determining the design rainfall depth for a 3-hour short-duration storm is a 2-year,2-hour precipitation isopluvial map (Figure 4.3.2).

The following equation is used to determine 3-hour precipitation for a selected return period.

$$P_{sds} = 1.06 * C_{sds} * P_{2yr2hr}$$

where:

P_{sds} = the 3-hour precipitation (inches) for a selected return period for the short-duration storm;

1.06 = the multiplier used for **all** climatic regions to convert x-year,2-hour precipitation to x-year,3-hour precipitation;

C_{sds} = the coefficient (from Table 4.2.11) for converting 2-year, 2-hour precipitation to x-year,2-hour precipitation depth; and

P_{2yr2hr} = the 2-year,2-hour precipitation (from Figure 4.3.2).

Table 4.2.11 lists values of the coefficient C_{sds} for selected return periods for various magnitudes of mean annual precipitation. An isopluvial map of average annual precipitation is shown in Figure 4.3.1 and can be used to determine the mean annual precipitation for the site.

Table 4.2.11 Values of the coefficient C_{sds} for using 2-year,2-hour precipitation to compute 2-hour* precipitation for selected periods of return.

Region	Mean Annual Precipitation (inches)	6-Month	1-Year	10-Year	25-Year	50-Year	100-Year
2	6-8	0.61	0.79	1.63	2.17	2.68	3.29
	8-10	0.62	0.80	1.60	2.09	2.55	3.09
	10-12	0.64	0.81	1.56	2.02	2.44	2.92
2, 3	12-16	0.66	0.82	1.51	1.90	2.26	2.66
3	16-22	0.67	0.83	1.47	1.82	2.13	2.48
1, 4	22-28	0.69	0.84	1.43	1.74	2.01	2.31
	28-40	0.70	0.85	1.40	1.68	1.92	2.19
	40-60	0.72	0.86	1.36	1.61	1.82	2.05
	60-120	0.74	0.87	1.33	1.55	1.74	1.93

*2-hour precipitation is converted to 3-hour precipitation using a multiplier of 1.06 for all recurrence intervals.

Note: Values of C_{sds} are based on the Generalized Extreme Value (GEV) distribution whose distribution parameters can be expressed as a function of mean annual precipitation for eastern Washington.

4.2.7 Rain-on-Snow and Snowmelt Design

The following information on snow considerations, including rain-on-snow and snowmelt design, is optional guidance for detention and water quality design when required by the local jurisdiction. Other cold weather considerations for BMP design are included in Section 5.2.3.

Considerations for Snow

In many regions, an inevitable consequence of cold weather is precipitation in the form of snow. Table 4.2.12 illustrates some typical snowfall amounts for eastern Washington as compiled by Desert Research Institute in Nevada. While snowfall amounts are often converted to water equivalents and treated as individual events for the purpose of predicting annual precipitation events, in fact snowfall from multiple events may accumulate over time thus creating storage of potential runoff volumes. This storage may be released gradually over time in the form of snowmelt or it may be converted to runoff rapidly by rain-on-snow events. Gradual melting can cause problems because the runoff may fill or saturate stormwater BMPs prior to an actual design event and consequently produce wet soil conditions and more runoff. Refreezing during cold evenings may exacerbate some of the problems.

Table 4.2.12 Average Annual Snowfall at Selected Locations in Eastern Washington

Location	Period of Record	Average Annual Snowfall (inches)
Asotin 14 SW	1976-2000	14.5
Cle Elum	1931-2000	80.5
Dayton 1 WSW	1931-2000	17.8
Ellensburg	1901-2000	27.7
Ephrata Airport FCWOS	1949-2000	18.3
Goldendale	1931-2000	25.0
Kennewick	1948-2000	6.9
Leavenworth 3 S	1948-2000	95.2
Methow 2 S	1970-2000	38.3
Newport	1927-2000	59.4
Othello 6 ESE	1941-2000	4.2
Prosser 4 NE	1931-2000	7.9
Pullman 2 NW	1940-2000	28.1
Quincy 1 S	1941-2000	13.2
Richland	1948-2000	8.5
Spokane WSO Airport	1889-2000	41.4
Walla Walla FAA Airport	1949-1995	17.4
Wenatchee	1877-2000	27.6
Yakima WSO AP	1946-2000	24.1

Because of the many physical factors involved, snowmelt is a complicated process, with large annual variations in the melting rate frequently occurring. While the criteria presented here address the affects of rain-on-snow and snowmelt, several simplifying assumptions are made. Where local data or experiences are available, more sophisticated methods should be substituted.

Rain-on-Snow Considerations

For water quality volume, rain-on-snow events can be important in many eastern Washington regions. Although the size of rainfall events typically used in BMP design may or may not produce a significant amount of snowmelt, runoff produced by these events is high because of frozen and saturated ground conditions beneath the snow cover. The actual melting and runoff processes are quite complicated and require information not readily available in most areas. The Stormwater Practices for Cold Climates document prepared by the Center for Watershed Protection suggested the following four-step simplified procedure. As with other referenced methodology, this approach has not been well tested for eastern Washington, however it does provides a basis for estimating rain-on-snow volumes which could be used and refined with experience.

Calculating Rain-on-Snow Volume (Center for Watershed Protection):

Step 1. Many rules for sizing water quality volumes are based on treating a rainfall event with a specified occurrence frequency, such as treating the 1-year,24-hour rainfall event. The same process has been proposed for rain-on-snow events. However, rather than including all precipitation events, it is necessary to develop a data set of rainfall events that occurred only for those months where snow is on the ground. Snow events, as well as non-runoff producing events ($P < 0.1$ inch), should be excluded from this data set. The result is a recurrence frequency for rain-on-snow events. Because the ground is frozen and/or saturated, this precipitation distribution is also the same as the runoff distribution.

Step 2. Calculate a similar rainfall distribution for months without snow cover.

Step 3. Determine the runoff distribution for months without snow cover. Because we have excluded non-runoff producing events from the distribution, the runoff is equal to:

$$R = 1.0 * P * (0.05 + 0.9 I)$$

If the impervious percentage (I) is known (assume 40 %) then, for months without snow:

$$R = 0.41 * P$$

Where P is the precipitation for a return frequency computed in Step 2. A runoff distribution for “summer” is developed by multiplying all of the precipitation values used in Step 2 by the 0.41 multiplier determined previously in this step.

Step 4. Take the "winter" runoff distribution data from Step 1 and combine it with the "summer" runoff distribution computed in Step 3. Sort the data and rank it accordingly to determine an overall annual runoff distribution. Determine the 90th percentile value and use it for design purposes as long as this value is greater than the summer precipitation event.

It should again be pointed out that this methodology does not include any contribution from snowmelt. As previously stated, it is predicated on the assumption that design storm precipitation quantities are not large enough to produce significant melt quantities.

The US Army Corps of Engineers developed an expression to estimate the melt as a function of precipitation and temperature. The equation is:

$$M_s = 0.00695 * (T_{rain} - 32)\ P_r$$

This equation predicts that 2.5 inches of rainfall precipitation (P_r) at a rainfall temperature of 50 ^oF would melt 0.31 inches of snow. Whether this represents a significant increase in required volume would depend on the site.

A note concerning the impacts of snowmelt is warranted. Because the ground is generally frozen during snowmelt or rain-on-snow events, the difference between pre- and post- project discharges are often quite small. For this reason, snowmelt and rain-on-snow events rarely need to be considered when designing for channel or overbank protection.

Additional Rain-on-Snow Considerations:

Rain-on-snow could affect the flow in the evaluation of the long-duration storms, especially in regions with high snowfall. Except for higher elevations with deeper snow packs, it should be assumed that a long-duration design storm results in the complete melting and runoff of the typical snow pack. To determine the typical snow pack, calculate the average daily snow depth from December to February which is available on the Internet for many eastern Washington locations. If the average daily snow depth is less than 1 inch, then the rain-on-snow effect can be considered negligible and should not be considered in the analysis. Assuming 20 percent moisture content, determine the water equivalent. A sample of the average daily snow depths and precipitation adjustment amount for selected cities is in Table 4.2.13.

Snowmelt can also be considered in water quality design. Melting snow from the roadways and from the snow piles alongside the roadways have significant amounts of pollutants generated from the vehicles, deicers, and roadway salts. The water quality facilities should be located downstream of the snowmelt areas and can be sized for snowmelt, especially in regions with high snowfall.

Table 4.2.13 Snowmelt adjustment factors

Location	Average daily snow depth (inches)	Water equivalent (inches) 24-hour storm precipitation adjustment	24-hour : 72-hour precipitation ratio, based on climate region	Regional storm precipitation adjustment (inches)
Colville	5.00	1.0	.70	.70
Clarkston	.33	N/A	N/A	N/A
Goldendale	1.67	.33	.67	.22
Moses Lake	.67	.13	.84	.11
Omak	4.67	.93	.75	.70
Pullman	1.33	.27	.70	.19
Richland	.33	N/A	N/A	N/A
Spokane Airport	2.33	.47	.75	.35
Walla Walla	1.00	.20	.75	.15
Wenatchee	2.67	.53	.84	.45
Yakima	2.00	.40	.84	.34

For projects that are located above 2500 feet elevation, a separate study or local data should be used as the average snow depth is significant and varies widely.

The assumption is that the entire average daily snow melt on the ground will melt during the long-duration storm. Since the long-duration storm is 72 hours in duration, the water equivalent for the peak 24 hours will be less than if the long-duration storm were only 24 hours. The adjustment factor is the ratio of the 24-hour precipitation to the 72-hour precipitation and varies based on climate region. In order to utilize the snowmelt factor with the long-duration storm hyetograph, the Long-Duration Storm Precipitation Adjustment should be added to the 24-hour design storm precipitation.

The CN used shall be for normal Antecedent Moisture Condition II.

If the average annual precipitation at the project site varies from the average annual precipitation at the nearest known snow depth record location, the average daily snow depth will also vary. To determine the estimated average daily snow depth, multiply the known average daily snow depth and all other factors by the ratio of average annual precipitation at the project site to the average annual precipitation at the record location.

For example: A project is located in Cashmere where the average annual precipitation is 14 inches. The nearest snow depth record location is Wenatchee. The snow depth at Wenatchee is 2.67 inches from Table

4.2.13 and the average annual precipitation from Figure 4.3.1 is 10 inches. The estimated snow depth for Cashmere is: 2.67 * 14/10 = 3.74 inches.

Snowmelt

In relatively dry regions that receive much of their precipitation as snowfall, the sizing is heavily influenced by the snowmelt event. A typical recommendation is to oversize the facility when average annual snowfall depth is greater than or equal to annual precipitation depth. This assumes snow is approximately 10% water. The sizing criteria for the treatment of water quality are based on the following four assumptions:

1. BMPs should be sized to treat the spring snowmelt event,
2. Snowmelt runoff is influenced by the moisture content of the spring snow pack and soil moisture,
3. No more than five percent of the annual runoff volume should bypass treatment during the spring snowmelt event, and
4. Because snowmelt occurs over several days, BMPs can treat a snowmelt volume greater than their size would indicate.

Although snowmelt occurs continuously throughout the winter and spring months, the characteristics and rates of runoff may vary. As rules of thumb, 1/2 of the snowfall is assumed to melt in the winter if the average daily maximum January temperature is < 25 ^{o}F and 2/3 of the snowfall melts if the temperature is between 25 and 35 ^{o}F. Winter melting events have high concentrations of soluble pollutants such as chlorides and metals because of "preferential elution" from the snow pack (Jeffries, 1988). Conversely, spring snowmelt is higher in suspended solids and hydrophobic elements, such as hydrocarbons, which can remain in the snow pack until the last five to ten percent of water leaves the snow pack (Marsalek, 1991).

Three methods for estimating snowmelt are available, as described below.

Snowmelt Method 1 (Stahre and Urbonas):

Although snowmelt rates can be as high as 0.15 inches/hour (0.151 cfs/acre) under extreme conditions, Stahre and Urbonas (1989) recommended the following minimum design values:

Snowmelt = Impervious surface area x 0.04 cfs/acre + Pervious surface area x 0.02 cfs/acre

Snowmelt Method 2 (US Army Corps of Engineers):

The above rates from the Stahre and Urbonas method are not universally accepted. The US Army Corps of Engineers proposed the following temperature index solution for daily snowmelt (M_s) in inches per day:

$$M_s = C_m (T_{air} - T_{base})$$

Where T_{air} is the average daily air temperature (^oF), T_{base} is the base temperature (typically around 32 ^oF when using average daily air temperature), and C_m is the melt-rate coefficient in inches/ ^oF. This coefficient can be variable depending on site conditions. The relative magnitude of this factor is shown in Table 4.2.14.

Table 4.2.14 Melt Rate Coefficients for Various Conditions (assuming T_{base} = 32 ^oF)

Case	T_{air} (^oF)	Melt (inches)	C_m (inches/ ^oF)	Comment
1	70	2.57	0.068	Clear, low albedo
2	70	2.40	0.073	Case 1 2/40% forest
3	65	1.51	0.040	Case 1 w/cloud cover
4	70	1.73	0.046	Case 1 w/fresh snow
5	50	3.24	0.180	Heavy rain, windy
6	50	2.92	0.163	Light rain, windy
7	50	1.11	0.062	Light rain, light wind

Snowmelt Method 3 (Center for Watershed Protection):

The Stormwater Practices for Cold Climates document prepared by the Center for Watershed Protection presents a straightforward methodology for calculating snowmelt runoff in seven steps. The method is general and a specific application for eastern Washington has not yet been developed. However, it does provide a basis for estimation which could be used and refined as more knowledge becomes available with experience. The procedure is as follows:

Step 1. The procedure is based on the assumption that over-sizing is necessary if the average annual precipitation is less than half the average annual snowfall depth. For example, if the average annual precipitation is 15 inches and the average annual snowfall is 16 inches (or more), over-sizing will be required.

Step 2. Determine the annual losses from sublimation and snow removal.

Step 3. Determine the annual water equivalent loss from winter snowmelt events. This requires an assumption regarding the amount of water in an inch of snow. Assuming that the water equivalence of the snow is 1:10, an average annual snowfall of 40 inches, and 15 percent lost to the combination of sublimation and snow removal, the total water amount is:

$$M_s = 0.1 * (40-(0.15*40)) = 3.4 \text{ inches}$$

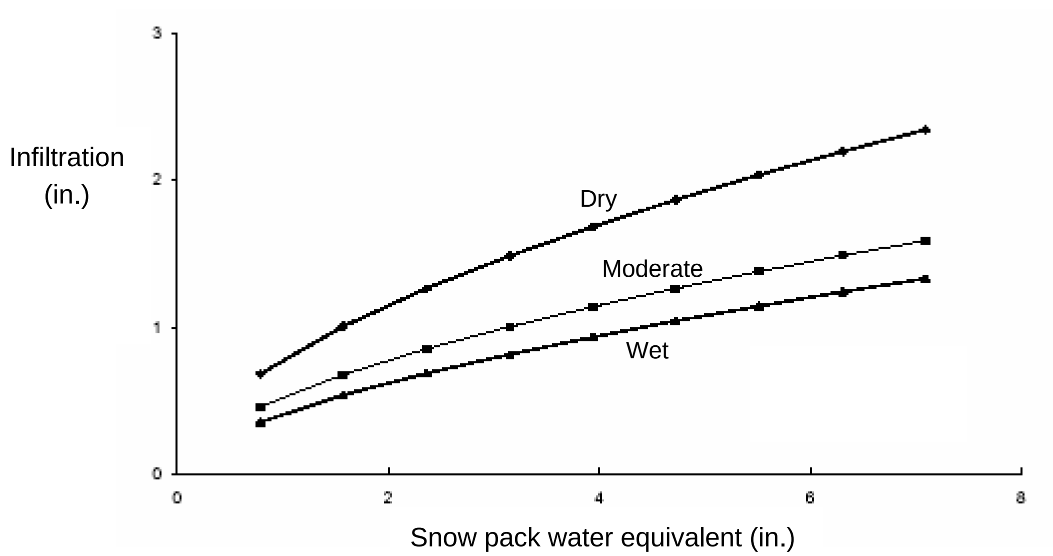
This factor is multiplied by the temperature factor (1/2 if the average daily maximum January temperature is < 25 °F and 2/3 if the temperature is between 25 and 35 °F). Assuming the average daily maximum January temperature is 24 °F, the final snow pack water equivalent (M_s) is 1.7 inches.

Step 4. Calculate the snowmelt runoff volume, R_s, using:

$$R_s = (1 - I)*(M_s - F) + (I)(M_s)$$

Where I is the impervious fraction of the watershed, F is the infiltration (inches), and Ms is the snow pack water equivalent (inches).

Figure 4.2.5 Snowmelt infiltration as a function of soil moisture



To continue the example, for moderate soil moisture conditions and 1.7 inches of snow pack water, the infiltration amount is 0.65 inches. Furthermore, if the impervious percent is 40%, then:

$$R_s = (1 - I)*(M_s - F) + (I)(M_s) = (1 - 0.4)*(1.7 - 0.65) + 0.4(1.7)$$

$$R_s = 1.31 \text{ inches}$$

Step 5. Determine the annual runoff volume. While there are several acceptable ways of computing this value, Shuler (1987) proposed a "Simple Method" whereby annual runoff (R) in inches is given by:

$$R = 0.9 * P * (0.05 + 0.9\ I)$$

Assuming the annual precipitation is 15 inches/year and the impervious coefficient is still 0.4, then:

$R = 0.9 * 15 * (0.05 + 0.9 * 0.4) = 5.54$ inches

Step 6. Determine the amount of runoff to be treated (T) for a 20-acre site.

$T = (R_s – 0.05 *R) * \text{Area} /12$

$T = (1.31 – 0.05*5.54)*(50)/12 = 4.3$ acre-feet

Step 7. Because snowmelt occurs over several days or even weeks, the BMP does not have to treat the entire water quality volume over a 24-hr period. A 50 percent reduction in the volume is used to determine how much storage is required. Thus, the water quality treatment volume (WQ_v) is given by:

$WQ_v = ½ * T = 2.15$ acre-feet

Finally, this volume should be compared with the volume from precipitation considerations to determine which is more conservative.

4.3 Precipitation Maps Link to separate file for maps

Precipitation maps for eastern Washington are in the following figures:

Figure 4.3.1: Average Annual Precipitation and Climate Regions

Figure 4.3.2: 2-year,2-hour Isopluvial Map

Figure 4.3.3: 2-year,24-hour Isopluvial Map

Figure 4.3.4: 10-year,24-hour Isopluvial Map

Figure 4.3.5: 25-year,24-hour Isopluvial Map

Figure 4.3.6: 50-year,24-hour Isopluvial Map

Figure 4.3.7: 100-year,24-hour Isopluvial Map

Electronic versions of the maps are available for downloading from the Department of Ecology website; GIS coverages also can be made available for Figures 4.3.3 through 4.3.7.

4.4 Single Event Hydrograph Methods

4.4.1 Introduction

Applicability: Single Event Hydrograph Methods are the required method for designing flow control BMPs. They are an allowable method for computing peak runoff rates and runoff volumes for design of runoff treatment BMPs. Single Event Hydrograph Methods include the Soil Conservation Service (SCS) Hydrograph and the Santa Barbara Urban Hydrograph (SBUH). Commercially available computer programs for these methods may be used if the sponsor's engineer acquires acceptance from the local jurisdiction. Such acceptance shall be obtained prior to submittal of plans and calculations.

Supplemental Guidelines: The SBUH method calculates only flow that will occur from surface runoff and thus is not accurate for large drainage basins where groundwater flow can be a major contributor to the total flow. The method is most accurate for drainage basins smaller than 100 acres and should not be used for drainage basins larger than 1,000 acres.

4.4.2 Hydrograph Design Process

This section presents the general process involved in conducting a hydrologic analysis using hydrograph methods to a) design retention/detention flow control facilities and b) determine water quality treatment volumes. The exact step-by-step method for entering data into a computer model varies with the different models and is not described here. See the documentation or Help module of the computer program. Pre-developed or existing and proposed-development site runoff conditions need to be determined and documented in the Stormwater Site Plan.

<u>The process for designing retention/detention **flow control facilities** is described as follows</u>:

Review Core Element #6 in Chapter 2 to determine all flow control requirements that will apply to the proposed project.

1. Identify the climate region and average annual precipitation from Figure 4.3.1.
2. Identify two rainfall depths from Figures 4.3.3 and 4.3.5
   - 2-year,24-hour
   - 25-year (or other recurrence interval(s) required by the agency or local jurisdiction), 24-hour
3. Determine the pre-developed or existing and the proposed-development drainage basin areas, and identify pervious and impervious area (in acres) for each condition.
4. Determine soil types and hydrologic groups (A, B, C, or D) from SCS maps.

5. Determine curve numbers for pervious and impervious areas using hydrologic soil groups for both the pre-developed or existing and the proposed-development conditions; see Table 4.5.2.
6. Determine times of concentration for both pre-developed or existing and proposed-development conditions; some computer models will do these calculations if the designer enters length, slope, roughness, and flow type.
7. Select storm hyetograph and analysis time interval; verify that the analysis time interval is appropriate for use with storm hyetograph time increment.
8. Input data obtained from Steps 2, 3, 5, 6, and 7 into the computer model for both the pre-developed or existing and the proposed-development conditions.
9. Have the computer model compute the hydrographs.
10. Review the peak flow rate for the pre-developed or existing condition in the 2-year and 25-year design storms. The allowable release rate for the entire volume of the 2-year storm is 50 percent of the pre-developed or existing 2-year peak flow rate. The allowable release rate for the 25-year storm is equal to the pre-developed or existing 25-year peak flow. Note that in some cases the pre-developed or existing 2-year peak flow rate may be 0 cfs, which means there is no discharge from the site. In this situation, the 2-year proposed-development flow volume must be retained as dead storage that will ultimately infiltrate or evaporate.
11. Review the peak flow rate for the proposed-development conditions in the 2-year and 25-year storms. Compare the increases in peak flow rates for 2-year and 25-year design storms to determine if there is an increase in runoff and a flow control facility is therefore required. Also determine whether the project qualifies for applying dispersion BMPs.
12. Assume a size for the detention facility and input this size into the computer model. Most computer models will allow a vault or a pond detention facility, with or without infiltration. Refer to the volume of the design storm hydrograph computed in Step 10 for a reasonable assumption of the detention volume required.
13. Assume a size for the orifice structure and input this size into the computer model. A single orifice at the bottom of the riser may suffice in some cases. In other projects, multiple orifices may result in decreased pond sizes. For a typical pond, a reasonable approximation is 1 inch of diameter orifice per 0.05 cfs outflow. Note that the design engineer should check with the local jurisdiction to determine the minimum allowable orifice diameter.

14. Use the computer model to route the proposed-development hydrographs through the detention facility and orifice structure. Compare the proposed-development peak outflow rates to the allowable release rates identified in Step 11.
15. If the proposed-development peak outflow rates exceed the allowable release rates, adjust the detention volume, orifice size, orifice height, and(or) number of orifices. Continue iterations utilizing the computer model and adjusting the parameters until the proposed-development outflow rates are less than or equal to the allowable release rates.
16. Calculations are complete.

The process for identifying **water quality treatment** volumes or flow rates is described as follows. Note that the data required for many of the initial steps are data that are utilized in designing retention/detention flow control facilities as described above.

1. Review Core Element #5 in Chapter 2 to determine all runoff treatment requirements that will apply to the proposed project.
2. Determine the climate region and average annual precipitation from Figure 4.3.1.
3. Determine one of the following rainfall depths (depending on the type of runoff treatment BMP) from Figure 4.3.2 or 4.3.3:
   - 2-year,2-hour *for flow-rate-based treatment BMPs*
   - 2-year,24-hour *for volume-based treatment BMPs*
4. Multiply the rainfall by the appropriate coefficient to convert the 2-year to the 6-month precipitation depth:
   - 1.06*C_{sds} from Table 4.2.11 for 6-month,3-hour precipitation
   - C_{wqs} from Table 4.2.9 for 6-month,24-hour precipitation
5. Determine the proposed-development drainage basin areas and identify the pervious and impervious areas (in acres) that contribute flow to the treatment BMP.
6. Determine soil types and hydrologic groups (A, B, C, or D) from SCS maps.
7. Determine curve numbers for the pervious and impervious area using the hydrologic soil group for the proposed-development conditions; see Table 4.5.2
8. Determine the time of concentration for the proposed-development conditions; some computer models will do this calculation if the designer enters length, slope, roughness, and flow type.

9. If modeling the short- or long-duration storm hyetograph, select the 3-hour short-duration storm hyetographs (see Table 4.2.4) or regional long-duration storm hyetographs for the climate region (see either Table 4.2.2 or Tables 4.2.5 to 4.2.8) and analysis time interval. Check to be certain that the analysis time interval is appropriate for use with the storm hyetograph time increment.
10. Input data obtained from Steps 4, 5, 7, 8, and 9 into the computer model for the proposed-development conditions and storm event.
11. Have the computer model compute the hydrograph.
12. To design flow-rate-based treatment BMPs, use the computed peak flow from the 6-month,3-hour hydrograph .
13. To design volume-based treatment BMPs, use the computed volume from the 6-month,24-hour (or long-duration design) hydrograph.

All storm event hydrograph methods require the input of parameters that describe the physical drainage basin characteristics. These parameters provide the basis from which the runoff hydrograph is developed. The following section describes one of the three key parameters used to develop the runoff hydrograph using the SCS or SBUH method: time of concentration. The other two parameters are area and curve number, which are described in Section 4.5.

4.4.3 Travel Time and Time of Concentration

The time of concentration for rainfall shall be computed for all overland flow, ditches, channels, gutters, culverts, and pipe systems. When using the SBUH or SCS methods, the time of concentration for the various surfaces and conveyances should be computed using the following methods, which are based on the methods described in Chapter 3, NRCS publication 210-VI-TR-55, Second Ed., June 1986.

Travel time (T_t) is the time it takes water to travel from one location to another in a watershed. T_t is a component of time of concentration (T_c), which is the time for runoff to travel from the hydraulically most distant point of the watershed. T_c is computed by summing all the travel times for consecutive components of the drainage conveyance system. T_c influences the shape and peak of the runoff hydrograph. Urbanization usually decreases T_c, thereby increasing the peak discharge. But T_c can be increased as a result of (a) ponding behind small or inadequate drainage systems, including storm drain inlets and road culverts, or (b) reduction of land slope through grading.

Water moves through a watershed as sheet flow, shallow concentrated flow, open channel flow, or some combination of these. The type that occurs is best determined by field inspection.

Travel time (T_t) is the ratio of flow length to flow velocity:

$$\mathbf{T_t = L / 60\,V}$$

where: **T_t** = travel time, in minutes
L = flow length, in feet
V = average velocity, in feet per second
60 = unit conversion factor from seconds to minutes

Time of concentration (T_c) is the sum of T_t values for the various consecutive flow segments.

$$\mathbf{T_c = T_{t_1} + T_{t_2} + \ldots T_{t_m}}$$

where: **T_c** = time of concentration, in minutes
m = the number of flow segments

Sheet Flow: Sheet flow is flow over plane surfaces. It usually occurs in the headwater of streams. With sheet flow, the friction value (n_s) (a modified Manning's effective roughness coefficient that includes the effect of raindrop impact; drag over the plane surface; obstacles such as litter, crop ridges, and rocks; and erosion and transportation of sediment) is used. These n_s values are for very shallow flow depths of about 0.1 foot and are only used for travel lengths up to 300 feet. Table 4.4.1 gives Manning's n. values for sheet flow for various surface conditions.

For sheet flow up to 300 feet, use Manning's kinematic solution to directly compute T_t:

$$\mathbf{T_t = 0.42 * (n_s * L)^{0.8} / ((P_{2yr2hr})^{0.5} * (s_o)^{0.4})}$$

where: **T_t** = travel time, in minutes
n_s = sheet flow Manning's effective roughness coefficient from Table 4.4.1
L = flow length, in feet
P_{2yr2hr} = 2-year,24-hour rainfall from Figure 4.3.3, in inches (**P_{2yr2hr}** may be called **P_2** in other forms of this equation)
s_o = slope of hydraulic grade line or land slope, in feet per feet

Shallow Concentrated Flow: After a maximum of 300 feet, sheet flow is assumed to become shallow concentrated flow. The average velocity for this flow can be calculated using the k_s values from Table 4.4.1 in which average velocity is a function of watercourse slope and type of channel. After computing the average velocity using the Velocity Equation below, the travel time (T_t) for the shallow concentrated flow segment can be computed using the Travel Time Equation described above.

Velocity Equation: A commonly used method of computing average velocity of flow, once it has measurable depth, is the following equation:

$$V = k \sqrt{s_o}$$

where: V = velocity (ft/s)
k = time of concentration velocity factor (ft/s)
s_o = slope of flow path (ft/ft)

"k" values in Table 4.4.1 have been computed for various land covers and channel characteristics with assumptions made for hydraulic radius using the following rearrangement of Manning's equation:

$$k = (1.49\,(R)^{0.667})/n$$

where: R = an assumed hydraulic radius
n = Manning's roughness coefficient for open channel flow, from Table 4.4.1 or 4.4.2

Open Channel Flow: Open channels are assumed to begin where surveyed cross section information has been obtained, where channels are visible on aerial photographs, or where lines indicating streams appear (in blue) on United States Geological Survey (USGS) quadrangle sheets. The k_c values from Table 4.4.1 used in the Velocity Equation above or water surface profile information can be used to estimate average flow velocity. Average flow velocity is usually determined for bank-full conditions. After average velocity is computed the travel time (T_t) for the channel segment can be computed using the Travel Time Equation above.

Lakes or Wetlands: Sometimes it is necessary to estimate the velocity of flow through a lake or wetland at the outlet of a watershed. This travel time is normally very small and can be assumed as zero. Where significant attenuation may occur due to storage effects, the flows should be routed using the "level-pool routing" technique described in Section 4.6.

Limitations: The following limitations apply in estimating travel time (T_t).

- Manning's kinematic solution should not be used for sheet flow longer than 300 feet.
- In watersheds with storm sewers, carefully identify the appropriate hydraulic flow path to estimate T_c. Storm sewers generally handle only a small portion of a large event. The rest of the peak flow travels by streets, lawns, and so on, to the outlet. Consult a standard hydraulics textbook to determine average velocity in pipes for either pressure or nonpressure flow.
- A culvert or bridge can act as a reservoir outlet if there is significant storage behind it. A hydrograph should be developed to this point and the "level pool routing" technique should be used to determine the outflow rating curve through the culvert or bridge.

Table 4.4.1 Values of "n" and "k" for use in computing Time of Concentration

FOR SHEET FLOW	n_s
Smooth surfaces (concrete, asphalt, gravel, or bare hard soil)	0.011
Fallow fields of loose soil surface (no vegetal residue)	0.05
Cultivated soil with crop residue (slope < 0.20 ft/ft)	0.06
Cultivated soil with crop residue (slope > 0.20 ft/ft)	0.17
Short prairie grass and lawns	0.15
Dense grass	0.24
Bermuda grass	0.41
Range, natural	0.13
Woods or forest, poor cover	0.40
Woods or forest, good cover	0.80
FOR SHALLOW, CONCENTRATED FLOW	k_s
Forest with heavy ground litter and meadows (n = 0.10)	3
Brushy ground with some trees (n =0.06)	5
Fallow or minimum tillage cultivation (n = 0.04)	8
High grass (n = 0.035)	9
Short grass, pasture and lawns (n = 0.030)	11
Newly-bare ground (n = 0.025)	13
Paved and gravel areas (n = 0.012)	27
CHANNEL FLOW (INTERMITTENT, R = 0.2)	k_c
Forested swale with heavy ground litter (n=0.10)	5
Forested drainage course/ravine with defined channel bed (n=0.050)	10
Rock-lined waterway (n=0.035)	15
Grassed waterway (n=0.030)	17
Earth-lined waterway (n=0.025)	20
CMP pipe (n=0.024)	21
Concrete pipe (n=0.012)	42
Other waterways and pipes	0.508/n
CHANNEL FLOW (CONTINUOUS STREAM, R =0.4)	k_c
Meandering stream with some pools (n=0.040)	20
Rock-lined stream (n=0.035)	23
Grassed stream (n=0.030)	27
Other streams, man-made channels and pipe	0.807/n

Table 4.4.2 Other values of the roughness coefficient "n" for channel flow

Type of Channel and Description	Manning's "n"*	Type of Channel and Description	Manning's "n"*
A. Constructed Channels		6. Sluggish reaches, weedy	
a. Earth, straight and uniform		deep pools	0.070
1. Clean, recently completed	0.018	7. Very weedy reaches, deep	
2. Gravel, uniform selection,	0.025	pools, or floodways with	
clean		heavy stand of timber and	
3. With short grass, few	0.027	underbrush	0.100
weeds		b. Mountain streams, no vegetation	
b. Earth, winding and sluggish		in channel, banks usually steep,	
1. No vegetation	0.025	trees and brush along banks	
2. Grass, some weeds	0.030	submerged at high stages	
3. Dense weeds or aquatic		1. Bottom: gravel, cobbles and	
plants in deep channels	0.035	few boulders	0.040
4. Earth bottom and rubble		2. Bottom: cobbles with large	
sides	0.030	boulders	0.050
5. Stony bottom and weedy		B-2 Flood plains	
banks	0.035	a. Pasture, no brush	
6. Cobble bottom and clean		1. Short grass	0.030
sides	0.040	2. High grass	0.035
c. Rock lined		b. Cultivated areas	
1. Smooth and uniform	0.035	1. No crop	0.030
2. Jagged and irregular	0.040	2. Mature row crops	0.035
d. Channels not maintained,		3. Mature field crops	0.040
weeds and brush uncut		c. Brush	
1. Dense weeds, high as flow		1. Scattered brush, heavy	
depth	0.080	weeds	0.050
2. Clean bottom, brush on		2. Light brush and trees	0.060
sides	0.050	3. Medium to dense brush	0.070
3. Same, highest stage of		4. Heavy, dense brush	0.100
flow	0.070	d. Trees	
4. Dense brush, high stage	0.100	1. Dense willows, straight	0.150
B. Natural Streams		2. Cleared land with tree	
B-1 Minor streams (top width		stumps, no sprouts	0.040
at flood stage < 100ft.)		3. Same as above, but with	
a. Streams on plain		heavy growth of sprouts	0.060
1. Clean, straight, full stage		4. Heavy stand of timber, a few	
no rifts or deep pools	0.030	down trees, little	
2. Same as above, but more		undergrowth, flood stage	
stones and weeds	0.035	below branches	0.100
3. Clean, winding, some		5. Same as above, but with	
pools and shoals	0.040	flood stage reaching	
4. Same as above, but some		branches	0.120
Weeds	0.040		
5. Same as 4, but more			
Stones	0.050		

*Note, these "n" values are "normal" values for use in analysis of channels. For conservative design for channel capacity the "maximum" values listed in other references should be considered. For channel bank stability the minimum values should be considered.

Example: The following is an example of travel time and time of concentration calculations.

Given: An existing drainage basin having a selected flow route composed of the following 4 segments: (Note: Drainage basin has a P_2 = 0.8 inches.)

Segment 1: L = 200 ft, Forest with good cover (sheet flow)
s_o = 0.03 ft/ft, n_s = 0.80
Segment 2: L = 300 ft, Pasture (shallow concentrated flow)
s_o = 0.04 ft/ft, k_s = 11
Segment 3: L = 300 ft, Grassed waterway (intermittent channel)
s_o = 0.05, k_c = 17
Segment 4: L = 500 ft, Grass-lined stream (continuous)
s_o = 0.02, k_c = 27

Calculate travel times (T_t) for each reach and then sum them to calculate the drainage basin time of concentration (T_c).

Segment 1: Sheet flow, (L < 300 feet)

$$T_t = \frac{0.42(n_s L)^{0.8}}{(P_2)^{0.5}(s_o)^{0.4}}$$

$$T_1 = \frac{(0.42)[(0.80)(200)]^{0.8}}{(0.8)^{0.3}(0.03)^{0.4}} = \underline{106\,\text{minutes}}$$

Segment 2: Shallow concentrated flow

$$V = k_s \sqrt{s_o}$$

$$V_2 = (11)\sqrt{(0.04)} = 2.2\,\text{ft/s}$$

$$T_2 = \frac{L}{60\,V} = \frac{(300)}{60(2.2)} = \underline{2\text{ minutes}}$$

Segment 3: Intermittent channel flow

$$V_4 = (17)\sqrt{(0.05)} = 3.8\,\text{ft/s}$$

$$T_4 = \frac{(300)}{60(3.8)} = \underline{1\,\text{minute}}$$

Segment 4: Continuous stream

$$V_5 = (27)\sqrt{(0.02)} = 3.8\,\text{ft/s}$$

$$T_5 = \frac{(500)}{60(3.8)} = \underline{2\text{ minutes}}$$

$T_c = T_1 + T_2 + T_3 + T_4$

T_c = 106 + 2 + 1 + 2 = <u>111 minutes</u>

It is important to note how the initial sheet flow segment's travel time dominates the time of concentration computation. This will nearly always be the case for relatively small drainage basins and in particular for the existing site conditions. This also illustrates the significant impact urbanization has on the surface runoff portion of the hydrologic process.

The time of concentration should be calculated for each significantly different slope. Travel time for flow in pipes, ditches and gutters should be computed as a function of the velocity as defined by the Manning formula.

4.4.4 Hydrograph Synthesis

This section presents a description of the Santa Barbara Urban Hydrograph (SBUH) method. This method is used to synthesize the runoff hydrograph from precipitation excess (time distribution of runoff) and time of concentration.

The SBUH method was developed by the Santa Barbara County Flood Control and Water Conservation District, California. The SBUH method directly computes a runoff hydrograph without going through an intermediate process (unit hydrograph) as the SCSUH method does. By comparison, the calculation steps of the SBUH method are much simpler and can be programmed on a calculator or a spreadsheet program. Commercial software is also available that can perform these calculations.

The SBUH method uses two steps to synthesize the runoff hydrograph:

Step 1: Compute the instantaneous hydrograph, and

Step 2: Compute the runoff hydrograph.

The instantaneous hydrograph is computed as follows:

$$l(t) = 60.5\ R(t)\ A/dt$$

where: $l(t)$ = the instantaneous hydrograph at each time step dt, in cubic feet per second

$R(t)$ = total runoff depth from both impervious and pervious runoffs at time increment dt, in inches. This is also known as precipitation excess.

A = area, in acres

dt = time interval, in minutes. Note: A maximum time interval of 5 minutes is used for all short-duration design storms. A maximum time interval of 30 minutes is used for all regional design storms.

The runoff hydrograph is then obtained by routing the instantaneous hydrograph through an imaginary reservoir with a time delay equal to the time of concentration of the drainage basin. The following equation estimates the routed flow:

$$Q(t+1) = Q(t) + w[l(t) + l(t+1) - 2Q(t)]$$

where: $Q(t)$ = the runoff hydrograph or routed flow, in cfs
$w = dt/(2T_c + dt)$, where T_c is the time of concentration
dt = time interval, in minutes

Example: To illustrate the SBUH method, Figure 4.4.1 shows a runoff hydrograph computed by this method. These examples were prepared using spreadsheet program. These examples illustrate how the method can be performed with a personal computer. In order to save space, time increments with all values equal to zero have been omitted.

Figure 4.4.1 Example SBUH Runoff Hydrograph

Existing Site Condition
REGION 2, 25-YEAR REGIONAL STORM

Given			
Area (ac.) = **5.0**	P_t (inches) = **1.6**	d_t (min.)= **30**	T_c (min)= **40**
w =routing constant =$d_t/(2T_c + d_t)$ = **0.2727**			
Pervious Area (ac.): Area = **5.0**	CN = **65**	S = (1000/CN) -10 = **5.38**	0.2S = **1.08**
Impervious Area (ac.): Area = **0.0**	CN = **98**	S = (1000/CN) -10 = **0.20**	0.2S = **0.04**

Column (3) = rainfall distribution
Column (4) = Column (3) x P_t
Column (5) = P = Accumulated sum of Column (4)
Column (6) = (If P ≤ 0.2S)= 0; (If P > 0.2S)= [(Column (5) – 0.2)^2/(Column (5) + 0.8S)] where PERVIOUS AREA S value is used
Column (7) = Column (6) of present step – Column (6) of previous step
Column (8) = (If P ≤ 0.2S)= 0; (If P > 0.2S)= [(Column (5) – 0.2)^2/(Column (5) + 0.8S)] where IMPERVIOUS AREA S value is used
Column (9) = Column (8) of present step – Column (8) of previous step
Column (10) = [(PERVIOUS AREA/TOTAL AREA) * Column (7)] + [(IMPERVIOUS AREA/TOTAL AREA) x Column (9)]
Column (11) = (60.5 x Column (10) x TOTAL AREA)/d_t
Column (12) = Column (12) of previous time + w[(Column (11) of previous time step + Column (11) of present time step) – (2 x Column (12) of previous time step)] where w = d_t /(2T_c+ d_t)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accumul. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
1	0	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
2	30	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
3	60	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
…											
90	2670	0.06220	0.100	0.934	0.000	0.000	0.495	0.089	0.000	0.0	0.00
91	2700	0.09330	0.149	1.083	0.000	0.000	0.632	0.137	0.000	0.0	0.00
92	2730	0.05275	0.084	1.167	0.001	0.001	0.711	0.079	0.001	0.0	0.00
93	2760	0.04025	0.064	1.232	0.004	0.003	0.772	0.061	0.003	0.0	0.01
94	2790	0.03717	0.059	1.291	0.008	0.004	0.828	0.056	0.004	0.0	0.02
95	2820	0.03483	0.056	1.347	0.013	0.005	0.881	0.053	0.005	0.0	0.03
96	2850	0.03307	0.053	1.400	0.018	0.005	0.931	0.051	0.005	0.1	0.04
97	2880	0.02893	0.046	1.446	0.024	0.005	0.976	0.044	0.005	0.1	0.05

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accumul. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
98	2910	0.02519	0.040	1.486	0.029	0.005	1.015	0.039	0.005	0.1	0.05
99	2940	0.02189	0.035	1.521	0.034	0.005	1.048	0.034	0.005	0.0	0.05
100	2970	0.01906	0.030	1.552	0.039	0.005	1.078	0.029	0.005	0.0	0.05
101	3000	0.01670	0.027	1.579	0.043	0.004	1.103	0.026	0.004	0.0	0.05
102	3030	0.01480	0.024	1.602	0.047	0.004	1.126	0.023	0.004	0.0	0.04
103	3060	0.01336	0.021	1.624	0.050	0.004	1.147	0.021	0.004	0.0	0.04
104	3090	0.01234	0.020	1.643	0.054	0.004	1.166	0.019	0.004	0.0	0.04
105	3120	0.01156	0.018	1.662	0.057	0.003	1.184	0.018	0.003	0.0	0.04
106	3150	0.01096	0.018	1.679	0.061	0.003	1.201	0.017	0.003	0.0	0.04
107	3180	0.01054	0.017	1.696	0.064	0.003	1.217	0.016	0.003	0.0	0.03
108	3210	0.01032	0.017	1.713	0.067	0.003	1.233	0.016	0.003	0.0	0.03
109	3240	0.01028	0.016	1.729	0.070	0.003	1.249	0.016	0.003	0.0	0.03
110	3270	0.01038	0.017	1.746	0.074	0.003	1.265	0.016	0.003	0.0	0.03
111	3300	0.01046	0.017	1.763	0.077	0.004	1.282	0.016	0.004	0.0	0.03
112	3330	0.01046	0.017	1.779	0.081	0.004	1.298	0.016	0.004	0.0	0.04
113	3360	0.01040	0.017	1.796	0.085	0.004	1.314	0.016	0.004	0.0	0.04
114	3390	0.01025	0.016	1.812	0.088	0.004	1.330	0.016	0.004	0.0	0.04
115	3420	0.01004	0.016	1.828	0.092	0.004	1.346	0.016	0.004	0.0	0.04
116	3450	0.00974	0.016	1.844	0.096	0.004	1.361	0.015	0.004	0.0	0.04
117	3480	0.00926	0.015	1.859	0.099	0.003	1.375	0.014	0.003	0.0	0.04
118	3510	0.00868	0.014	1.873	0.102	0.003	1.389	0.014	0.003	0.0	0.04
119	3540	0.00832	0.013	1.886	0.106	0.003	1.402	0.013	0.003	0.0	0.03
120	3570	0.00781	0.012	1.899	0.109	0.003	1.414	0.012	0.003	0.0	0.03
121	3600	0.00500	0.008	1.907	0.111	0.002	1.422	0.008	0.002	0.0	0.03
122	3630	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.02
123	3660	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.01
124	3690	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.00
125	3720	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.00
…											
145	4320	0.00000	0.000	1.907	0.111	0.000	1.422	0.000	0.000	0.0	0.00

Figure 4.4.1 (continued) Example SBUH Runoff Hydrograph

Proposed Development Site Condition
REGION 2, 25-YEAR REGIONAL STORM

Given			
Area (ac.) = **5.0**	P_t (inches) = **1.6**	d_t (min.)= **30**	T_c (min)= **5**
w =routing constant =$d_t/(2T_c + d_t)$ = **0.750**			
Pervious Area (ac.): Area = **0.5**	CN = **65**	S = (1000/CN) -10 = **5.38**	0.2S = **1.08**
Impervious Area (ac.): Area = **4.5**	CN = **98**	S = (1000/CN) -10 = **0.20**	0.2S = **0.04**

Column (3) = rainfall distribution
Column (4) = Column (3) x P_t
Column (5) = P = Accumulated sum of Column (4)
Column (6) = (If P ≤ 0.2S)= 0; (If P > 0.2S)= [(Column (5) – 0.2)^2/(Column (5) + 0.8S)] where PERVIOUS AREA S value is used
Column (7) = Column (6) of present step – Column (6) of previous step
Column (8) = (If P ≤ 0.2S)= 0; (If P > 0.2S)= [(Column (5) – 0.2)^2/(Column (5) + 0.8S)] where IMPERVIOUS AREA S value is used
Column (9) = Column (8) of present step – Column (8) of previous step
Column (10) = [(PERVIOUS AREA/TOTAL AREA) * Column (7)] + [(IMPERVIOUS AREA/TOTAL AREA) x Column (9)]
Column (11) = (60.5 x Column (10) x TOTAL AREA)/d_t
Column (12) = Column (12) of previous time + w[(Column (11) of previous time step + Column (11) of present time step) – (2 x Column (12) of previous time step)] where w = d_t /(2T_c+ d_t)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accum. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
1	0	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
2	30	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
3	60	0.00000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.0	0.00
…											
22	630	0.01669	0.027	0.046	0.000	0.000	0.000	0.000	0.000	0.0	0.00
23	660	0.02831	0.045	0.092	0.000	0.000	0.010	0.010	0.009	0.1	0.07
24	690	0.04680	0.075	0.167	0.000	0.000	0.048	0.038	0.034	0.3	0.29
25	720	0.03120	0.050	0.217	0.000	0.000	0.081	0.033	0.030	0.3	0.34
26	750	0.02549	0.041	0.257	0.000	0.000	0.111	0.030	0.027	0.3	0.26
27	780	0.01451	0.023	0.281	0.000	0.000	0.129	0.018	0.016	0.2	0.20
28	810	0.00445	0.007	0.288	0.000	0.000	0.135	0.006	0.005	0.1	0.06
29	840	0.00202	0.003	0.291	0.000	0.000	0.138	0.003	0.002	0.0	0.02

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accum. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
30	870	0.00192	0.003	0.294	0.000	0.000	0.140	0.002	0.002	0.0	0.02
31	900	0.00172	0.003	0.297	0.000	0.000	0.142	0.002	0.002	0.0	0.02
32	930	0.00152	0.002	0.299	0.000	0.000	0.144	0.002	0.002	0.0	0.02
33	960	0.00132	0.002	0.301	0.000	0.000	0.146	0.002	0.002	0.0	0.02
34	990	0.00112	0.002	0.303	0.000	0.000	0.147	0.001	0.001	0.0	0.01
35	1020	0.00092	0.001	0.305	0.000	0.000	0.149	0.001	0.001	0.0	0.01
36	1050	0.00072	0.001	0.306	0.000	0.000	0.150	0.001	0.001	0.0	0.01
37	1080	0.00052	0.001	0.307	0.000	0.000	0.150	0.001	0.001	0.0	0.01
38	1110	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
39	1140	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
…											
72	2130	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
73	2160	0.00000	0.000	0.307	0.000	0.000	0.150	0.000	0.000	0.0	0.00
74	2190	0.00544	0.009	0.315	0.000	0.000	0.157	0.007	0.006	0.1	0.05
75	2220	0.00856	0.014	0.329	0.000	0.000	0.169	0.011	0.010	0.1	0.10
76	2250	0.01000	0.016	0.345	0.000	0.000	0.182	0.013	0.012	0.1	0.12
77	2280	0.01200	0.019	0.364	0.000	0.000	0.198	0.016	0.015	0.1	0.14
78	2310	0.01300	0.021	0.385	0.000	0.000	0.216	0.018	0.016	0.2	0.16
79	2340	0.01400	0.022	0.407	0.000	0.000	0.235	0.019	0.017	0.2	0.17
80	2370	0.01500	0.024	0.431	0.000	0.000	0.256	0.021	0.019	0.2	0.19
81	2400	0.01600	0.026	0.457	0.000	0.000	0.279	0.023	0.020	0.2	0.20
82	2430	0.01700	0.027	0.484	0.000	0.000	0.304	0.024	0.022	0.2	0.22
83	2460	0.01869	0.030	0.514	0.000	0.000	0.331	0.027	0.024	0.2	0.24
84	2490	0.02281	0.036	0.551	0.000	0.000	0.364	0.033	0.030	0.3	0.29
85	2520	0.02832	0.045	0.596	0.000	0.000	0.406	0.042	0.038	0.4	0.37
86	2550	0.03050	0.049	0.645	0.000	0.000	0.451	0.045	0.041	0.4	0.41
87	2580	0.03350	0.054	0.698	0.000	0.000	0.502	0.050	0.045	0.5	0.45
88	2610	0.03650	0.058	0.757	0.000	0.000	0.557	0.055	0.050	0.5	0.50
89	2640	0.04842	0.077	0.834	0.000	0.000	0.631	0.074	0.067	0.7	0.63
90	2670	0.06220	0.100	0.934	0.000	0.000	0.727	0.096	0.086	0.9	0.84
91	2700	0.09330	0.149	1.083	0.000	0.000	0.871	0.145	0.130	1.3	1.22
92	2730	0.05275	0.084	1.167	0.001	0.001	0.954	0.082	0.074	0.7	0.94
93	2760	0.04025	0.064	1.232	0.004	0.003	1.017	0.063	0.057	0.6	0.52
94	2790	0.03717	0.059	1.291	0.008	0.004	1.075	0.058	0.053	0.5	0.57
95	2820	0.03483	0.056	1.347	0.013	0.005	1.130	0.055	0.050	0.5	0.49
96	2850	0.03307	0.053	1.400	0.018	0.005	1.182	0.052	0.047	0.5	0.49
97	2880	0.02893	0.046	1.446	0.024	0.005	1.227	0.046	0.042	0.4	0.43
98	2910	0.02519	0.040	1.486	0.029	0.005	1.267	0.040	0.036	0.4	0.37
99	2940	0.02189	0.035	1.521	0.034	0.005	1.301	0.034	0.032	0.3	0.33
100	2970	0.01906	0.030	1.552	0.039	0.005	1.331	0.030	0.028	0.3	0.28

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
					Pervious Area		Impervious Area				
Time Incr.	Time (min)	Rainfall Distrib. (fraction)	Incre. Rainfall (inches)	Accum. Rainfall (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Accum. Runoff (inches)	Incre. Runoff (inches)	Total Runoff (inches)	Instant Flowrate (cfs)	Design Flowrate (cfs)
101	3000	0.01670	0.027	1.579	0.043	0.004	1.358	0.026	0.024	0.2	0.25
102	3030	0.01480	0.024	1.602	0.047	0.004	1.381	0.023	0.021	0.2	0.22
103	3060	0.01336	0.021	1.624	0.050	0.004	1.402	0.021	0.019	0.2	0.20
104	3090	0.01234	0.020	1.643	0.054	0.004	1.422	0.019	0.018	0.2	0.18
105	3120	0.01156	0.018	1.662	0.057	0.003	1.440	0.018	0.017	0.2	0.17
106	3150	0.01096	0.018	1.679	0.061	0.003	1.457	0.017	0.016	0.2	0.16
107	3180	0.01054	0.017	1.696	0.064	0.003	1.474	0.017	0.015	0.2	0.16
108	3210	0.01032	0.017	1.713	0.067	0.003	1.490	0.016	0.015	0.2	0.15
109	3240	0.01028	0.016	1.729	0.070	0.003	1.506	0.016	0.015	0.2	0.15
110	3270	0.01038	0.017	1.746	0.074	0.003	1.523	0.016	0.015	0.2	0.15
111	3300	0.01046	0.017	1.763	0.077	0.004	1.539	0.017	0.015	0.2	0.15
112	3330	0.01046	0.017	1.779	0.081	0.004	1.556	0.017	0.015	0.2	0.15
113	3360	0.01040	0.017	1.796	0.085	0.004	1.572	0.016	0.015	0.2	0.15
114	3390	0.01025	0.016	1.812	0.088	0.004	1.589	0.016	0.015	0.2	0.15
115	3420	0.01004	0.016	1.828	0.092	0.004	1.604	0.016	0.015	0.1	0.15
116	3450	0.00974	0.016	1.844	0.096	0.004	1.620	0.015	0.014	0.1	0.14
117	3480	0.00926	0.015	1.859	0.099	0.003	1.635	0.015	0.014	0.1	0.14
118	3510	0.00868	0.014	1.873	0.102	0.003	1.648	0.014	0.013	0.1	0.13
119	3540	0.00832	0.013	1.886	0.106	0.003	1.662	0.013	0.012	0.1	0.12
120	3570	0.00781	0.012	1.899	0.109	0.003	1.674	0.012	0.011	0.1	0.12
121	3600	0.00500	0.008	1.907	0.111	0.002	1.682	0.008	0.007	0.1	0.08
122	3630	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.01
123	3660	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00
124	3690	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00
…											
144	4290	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00
145	4320	0.00000	0.000	1.907	0.111	0.000	1.682	0.000	0.000	0.0	0.00

4.5 SCS Curve Number Equations

4.5.1 Introduction

Applicability: The SCS Curve Number equation is an allowable method for computing storage volumes for volume based treatment BMPs based on the SCS hydrograph method. The SCS curve numbers are also used in the Single Event Hydrograph Methods such as SCS Hydrograph and Santa Barbara Urban Hydrograph.

The primary source for this section is the Surface Water Management Manual for Western Washington, by Dept. of Ecology, 2001 and Urban Hydrology for Small Watersheds TR-55, by Natural Resources Conservation Service, 1986.

This method can be used to size the volume of treatment BMPs when the design is based on the volume of runoff. Computer models are not required for this method. Required input consists of precipitation, pervious and impervious area and curve numbers.

4.5.2 Area

Drainage sub-basin areas should be delineated in a manner that runoff characteristics are as homogeneous as practicable and in reasonable configurations. Sub-basin configurations should be contiguous and consistent with surface runoff patterns. Refer to 4.5.3 Curve Number for discussion regarding when weighted averaging is appropriate and not appropriate.

4.5.3 Curve Number

The Natural Resources Conservation Service (NRCS, formerly the Soil Conservation Service) has for many years conducted studies into the runoff characteristics of various land types. After gathering and analyzing extensive data, the NRCS has developed relationships between land use, soil type, vegetation cover, interception, infiltration, surface storage, and runoff. These relationships have been characterized by a single runoff coefficient called a “curve number” (CN). The National Engineering Handbook - Section 4: Hydrology (NEH-4, SCS, 1985) contains a detailed description of the development and use of the curve number method. The CN indicates the runoff potential of a watershed. Higher CNs have a higher potential for runoff. The CN is a combination of a hydrologic soil group, a land use, and a treatment class (cover).

NRCS is considering revisions to the curve numbers but, at the time of this writing, has not completed that effort. When revised curve numbers are adopted by NRCS they should be considered for use in lieu of the values published herein.

The combination of soil type and land use is called the “soil-cover complex.” The soil-cover complexes have been assigned to one of four hydrologic soil groups, according to their runoff characteristics. SCS has classified over 4,000 soil types into these four soil groups. Table 4.5.1 shows the hydrologic soil group of some of the common soils in eastern Washington and provides a brief description of the four hydrologic soil group classifications. For details on the hydrologic soil group for other soil types refer to the SCS maps published for each county.

Table 4.5.1 Hydrologic Soil Groups of Selected Soils in Eastern Washington. See SCS Soils Maps for additional soil and hydrologic groups

Soil Group	Hydrologic Group	Soil Group	Hydrologic Group
Athena	B	Laketon	C
Bernhill	B	Lance	B
Bong	A	Larkin	B
Bonner	B	Latah	D
Brickel	C	Marble	A
Bridgeson	D	Mondovi	B
Caldwell	C	Moscow	C
Cedonia	B	Naff	B
Cheney	B	Narcisse	C
Clayton	B	Nez Perce	C
Cocolalla	D	Palouse	B
Dearyton	C	Peone	D
Dragoon	C	Phoebe	B
Eloika	B	Reardan	C
Emdent	D	Schumacher	B
Freeman	C	Semiahmoo	D
Garfield	C	Snow	B
Garrison	B	Speigle	B
Glenrose	B	Spokane	C
Green Bluff	B	Springdale	A
Hagen	B	Tekoa	C
Hardesty	B	Uhlig	B
Hesseltine	B	Vassar	B
Konner	D	Wethey	C
Lakesol	B	Wolfeson	C

Source: U.S. Soil Conservation Service: TR-55, Second Edition, June 1986, Appendix A.

Hydrologic Soil Group Classifications

A. Low runoff potential: Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well-to-excessively drained sands or gravels. These soils have a high rate of water transmission.

B. Moderately low runoff potential: Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Moderately high runoff potential: Soils have slow infiltration rates when thoroughly wetted, and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.

D. High runoff potential: Soils having very slow infiltration rates when thoroughly wetted, and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

The following are important criteria/considerations for selection of CN values:

Many factors may affect the CN value for a given land use. For example, the movement of heavy equipment over bare ground may compact the soil so that it has a lesser infiltration rate and greater runoff potential than would be indicated by strict application of the CN value based on predevelopment conditions at the site.

Separate CN values must be selected for the pervious and impervious areas of an urban basin or sub-basin. For all developed areas, the percent impervious must be estimated from best available plans, topography, or aerial photography and verified by field reconnaissance. Generally, the pervious area CN value shall be a weighted average of all the pervious area CN values within the sub-basin. However, if two large homogeneous areas (such as a parking lot and a park) within the same sub-basin have CN values which differ by more than 20 points, separate hydrographs need to be generated for the two areas and the hydrographs then summed. See the example provided later in this section.

Directly connected impervious areas are areas such as roofs and driveways from which runoff directly enters the drainage system without first traversing an area of pervious ground. Unconnected impervious areas are areas whose runoff is spread over a pervious area as sheet flow and include such items as a tennis court in the middle of a lawn. Unconnected impervious areas can be weighted with pervious areas.

Table 4.5.2 gives CNs for agricultural, suburban, and urban land use classifications. These Curve Number values listed in Table 4.5.2 are applicable under normal antecedent moisture conditions (AMC II) and are the basis of design in eastern Washington.

High groundwater or shallow bedrock can cause a significant increase in runoff. If either of these conditions exists, it needs to be addressed by the design engineer. For a more complete discussion of computing weighted CN values, see NRCS publication 210-VI-TR-55, Second Edition, June 1986.

Table 4.5.2 Runoff Curve Numbers (CNs) for selected agricultural, suburban, and urban areas

Cover type and hydrologic condition	CNs for hydrologic soil group A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, landscaping, etc.)[1]				
Poor condition (grass cover <50% of the area)	68	79	86	89
Fair condition (grass cover on 50% to 75% of the area)	49	69	79	84
Good condition (grass cover on >75% of the area)	39	61	74	80
Impervious areas:				
Open water bodies: lakes, wetlands, ponds etc.	100	100	100	100
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)	98	98	98	98
Porous pavers and permeable interlocking concrete (assumed as 85% impervious and 15% lawn)				
Fair lawn condition (weighted average CNs)	95	96	97	97
Gravel (including right-of-way)	76	85	89	91
Dirt (including right-of-way)	72	82	87	89
Pasture, grassland, or range-continuous forage for grazing				
Poor condition (ground cover <50% or heavily grazed with no mulch).	68	79	86	89
Fair condition (ground cover 50% to 75% and not heavily grazed)	49	69	79	84
Good condition (ground cover >75% and lightly or only occasionally grazed)	39	61	74	80
Cultivated agricultural lands				
Row Crops (good) e.g., corn, sugar beets, soy beans	64	75	82	85
Small Grain (good) e.g., wheat, barley, flax	60	72	80	84
Meadow (continuous grass, protected from grazing and generally mowed for hay)	30	58	71	78
Brush (brush-weed-grass mixture with brush the major element)				
Poor (<50% ground cover)	48	67	77	83
Fair (50% to 75% ground cover)	35	56	70	77
Good (>75% ground cover)	30[2]	48	65	73
Woods-grass combination (orchard or tree farm)[3]				
Poor	57	73	82	86
Fair	43	65	76	82
Good	32	58	72	79
Woods				
Poor (Forest litter, small trees, and brush destroyed by heavy grazing or regular burning	45	66	77	83
Fair (Woods are grazed but not burned, and some forest litter covers the soil)	36	60	73	79
Good (Woods are protected from grazing, and litter and brush adequately cover the soil)	30	55	70	77
Herbaceous (mixture of grass, weeds, and low-growing brush, with brush the minor element)[4]				
Poor (<30% ground cover)		80	87	93
Fair (30% to 70% ground cover)		71	81	89
Good (>70% ground cover)		62	74	85
Sagebrush with grass understory[4]				
Poor (<30% ground cover)		67	80	85
Fair (30% to 70% ground cover)		51	63	70
Good (>70% ground cover)		35	47	55
For a more detailed and complete description of land use curve numbers refer to chapter two (2) of the Soil Conservation Service's Technical Release No. 55 , (210-VI-TR-55, Second Ed., June 1986).				

[1] Composite CNs may be computed for other combinations of open space cover type.

[2] Actual curve number is less than 30; use CN = 30 for runoff computations.

[3] CNs shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CNs for woods and pasture.

[4] Curve numbers have not been developed for group A soils.

Table 4.5.3 Curve Number conversions for Antecedent Moisture Conditions (Case Ia = 0.2 S)

CN for AMC II	CN for AMC I	CN for AMC III	CN for AMC II	CN for AMC I	CN for AMC III
100	100	100	76	58	89
99	97	100	75	57	88
98	94	99	74	55	88
97	91	99	73	54	87
96	89	99	72	53	86
95	87	98	71	52	86
94	85	98	70	51	85
93	83	98	69	50	84
92	81	97	68	48	84
91	80	97	67	47	83
90	78	96	66	46	82
89	76	96	65	45	82
88	75	95	64	44	81
87	73	95	63	43	80
86	72	94	62	42	79
85	70	94	61	41	78
84	68	93	60	40	78
83	67	93	59	39	78
82	66	92	58	38	76
81	64	92	57	37	75
80	63	91	56	36	75
79	62	91	55	35	74
78	60	90	54	34	73
77	59	89	50	31	70

Source: SCS-NEH4. Table 10.1.

Antecedent Moisture Condition: The moisture condition in a soil at the onset of a storm event, referred to as the antecedent moisture condition (AMC), has a significant effect on both the volume and rate of runoff. Recognizing that fact, the SCS developed three antecedent soil moisture conditions that are labeled conditions I, II, and III. The description of each condition is:

AMC I: soils are dry but not to wilting point

AMC II: average conditions

AMC III: heavy rainfall, or light rainfall and low temperatures have occurred within the last 5 days; near saturated or saturated soil

Table 4.5.4 gives seasonal rainfall limits for the three antecedent soil moisture conditions.

Table 4.5.4 Total 5-day antecedent rainfall (inches)

AMC	Dormant Season	Growing Season
I	Less than 0.5	Less than 1.4
II	0.5 to 1.1	1.4 to 2.1
III	Over 1.1	Over 2.1

Varying antecedent moisture conditions are used in the design of evaporation ponds in Section 6.4. See Table 4.5.3 for the curve number conversions for different antecedent moisture conditions for the case of Ia = 0.2S. For other conversion, see the SCS National Engineering Handbook No. 4, 1985.

Supplemental Guidelines: Local jurisdictions may wish to restrict the curve numbers used to describe the pre-developed or existing condition and generate the runoff in the proposed development condition. The lower curve numbers result in lower runoff and mitigate for past changes to the natural drainage patterns. Restricting the allowable curve numbers can also reduce the subjectivity that is inherent in the selection of curve numbers.

Example: The following is an example of how CN values are selected for a sample project.

Select CNs for the following development:

Existing land use: woods (thin stand, poor cover)

Future land use: 80% impervious

Basin size: 10 acres

Soil type: 80% Garfield, 20% Bonner, split between the pervious and impervious areas.

Table 4.5.1 shows that Garfield soil belongs to the "C" hydrologic soil group and Bonner soil belongs to the "B" group. Therefore, for the existing condition, CNs of 77 and 66 are read from Table 4.5.2 and area weighted to obtain a CN value of 75.

For the proposed-development condition with 80% impervious, the impervious and pervious areas are 8.0 acres and 2.0 acres, respectively. The impervious area CN-value is 98. The 2.0 acres of pervious area consists of 70 percent grass landscaping covering the same proportions of Garfield and Bonner soil (80% and 20% respectively). Therefore, CNs of 79 and 69 are read from Table 4.5.2 fair condition open space and area weighted to obtain a pervious area CN value of 77. The results of this example are summarized in the following table:

On-Site Condition	Existing	Proposed
Land use	Woods	Multi-Family
Pervious area	10.0 ac.	2.0 ac.
CN of pervious area	75	77
Impervious area	0 ac	8.0 ac
CN of impervious area	---	98

SCS Curve Number Equations: The rainfall-runoff equation of the SCS curve number method relate a land area's runoff depth (precipitation excess) to the precipitation it receives and to its natural storage capacity. The amount of runoff from a given watershed is solved with the following equations:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S}$$

$$S = \frac{1000}{CN} - 10$$

$$Q = 0 \quad \textit{for} \quad P < 0.2S$$

where:

Q = the actual direct runoff depth (inches)

P = the total rainfall depth over the area (inches)

S = the potential abstraction or potential maximum natural detention over the area due to infiltration, storage, etc. (inches)

CN = the runoff curve number

The combination of the above equations allows for estimation of the total runoff volume by computing the total runoff depth, Q, given the total precipitation depth, P for the storm of interest.

Example: The following is an example for determining design treatment volume.

Project location:	Walla Walla
Area requiring treatment:	4.5 acres, paved surfaces
CN:	98
S:	(1000/98) – 10 = 0.20
$P_{2\text{-year},24\text{-hour}}$, from Figure 4.3.3:	1.2 inches
C_{wqs} for Region 3, from Table 4.2.9:	0.69
24-hour to regional storm precipitation depth conversion factor for Region 3, from Table 4.2.10:	1.06

The total amount of rainfall during the **24-hour storm** is:

$P_{wqs} = C_{wqs} * P_{2\text{-year},24\text{-hour}}$ = (0.69) (1.2 inches) = 0.83 inches

The total amount of rainfall during the **regional storm** is:

$$P_{wqs} = (0.69)\ (1.2 \text{ inches})\ (1.06) = 0.88 \text{ inches}$$

Continuing on with the rainfall from the **regional storm**, the amount (*depth*) of rainfall that becomes runoff is:

$$Q = [0.88 - 0.2\ (0.20)]^2 / [0.88 + 0.8\ (0.20)] = 0.68 \text{ inches}$$

This depth value represents inches over the entire contributing area. The total *volume* of runoff is found by multiplying this depth by the area, with necessary conversion from inches*acres to cubic feet:

$$\text{Total runoff volume } (ft^3) = (3{,}630\ ft^3/\text{acre-in})\ (Q)\ (A)$$

The **total runoff volume** is:

$$3{,}630\ ft^3/\text{acre-in} * 0.68 \text{ inches} * 4.5 \text{ acres} = 11{,}108\ ft^3$$

This is the basis for design of runoff treatment BMPs for which the design is based on the total volume of runoff during the water quality design storm.

When developing the runoff hydrograph, the above equation for Q is used to compute the incremental runoff depth for each time interval from the incremental precipitation depth given by the design storm hyetograph. This time distribution of runoff depth is often referred to as the precipitation excess and provides the basis for synthesizing the runoff hydrograph.

4.6 Level-Pool Routing Method

This section presents a general description of the methodology for routing a hydrograph through an existing retention/detention facility or closed depression, or for sizing a new retention/detention facility using hydrograph analysis.

The "level pool routing" technique presented here is one of the simplest and most commonly used hydrograph routing methods. This method is described in "Handbook of Applied Hydrology," Chow, Ven Te, 1964, and elsewhere, and is based on the continuity equation:

Inflow - Outflow = Change in storage

$$\left[\frac{I_1 + I_2}{2} - \frac{O_1 + O_2}{2}\right] = \frac{\Delta S}{\Delta t} = S_2 - S_1$$

where: I = Inflow at time 1 and time 2

O = Outflow at time 1 and time 2

S = Storage at time 1 and time 2

Δt = Time interval, or time 2 minus time 1

The time interval, Δt, must be consistent with the time interval used in developing the inflow hydrograph. The time interval used for the 6-hour storm is 5 minutes while the time interval for the 72-hour storm is 30 minutes. The Δt variable can be eliminated by dividing it into the storage variables to obtain the following rearranged equation:

$$I_1 + I_2 + 2S_1 - O_1 = O_2 + 2S_2$$

If the time interval, Δt, is in minutes, the units of storage (S) are now [cubic feet/min] which can be converted to cfs by multiplying by 1 min/60 sec.

The terms on the left-hand side of the equation are known from the inflow hydrograph and from the storage and outflow values of the previous time step. The unknowns O_2 and S_2 can be solved interactively from the given stage-storage and stage-discharge curves.

The following steps are required in performing level-pool hydrograph routing:

- Develop stage-storage relationship, which is a function of inflow and pond geometry.
- Develop the routing curve for the hydrograph and pond, which is a graph of outflow from the pond at a given stage versus the quantity O + 2S for the same stage. The outflow is a function of stage (head above the orifice) and the control structure configuration.
- Route the inflow hydrograph through the proposed facility by applying the continuity equation above at each time step, where the inflow hydrograph supplies values of I, the stage-storage relationship supplies values of S, and the routing curve supplies values of O.

The commercially available SBUH hydrograph computer models use the level pool routing methodology to shift hydrographs and size infiltration and detention facilities.

4.7 Rational Method

4.7.1 Introduction

The primary source for this section is the WSDOT Hydraulics Manual, 1998.

Applicability: The rational method is an allowable method for computing peak runoff rates for flow based runoff treatment BMPs such as biofiltration swales and oil/water separators. It is also a common method for computing the peak runoff rate for design of drywells and conveyance systems.

Supplemental Guidelines: The greatest accuracy is obtained for areas smaller than 100 acres and for developed conditions with large areas of impervious surface (e.g., pavement, roof tops). Basins up to 1,000 acres may be evaluated using the rational formula; however, results for large basins often do not properly account for effects of infiltration and thus are less accurate.

Procedure: Design peak runoff rates may be determined by the Rational formula:

$$\mathbf{Q = C\ I\ A}$$

where: **Q** = Runoff, in cubic feet per second
C = Runoff coefficient
I = Rainfall intensity, in inches per hour
A = Contributing area, in acres

The runoff coefficient C should be based on Table 4.7.1.

The coefficients in Table 4.7.1 are applicable for peak storms of 10-year or less frequency. Less frequent, higher intensity storms will require the use of higher coefficients because infiltration and other losses have a proportionally smaller effect on runoff. Generally, the coefficient should be increased by 10 percent when designing for a 25-year frequency; by 20 percent for 50-year; and by 25 percent for 100-year. The runoff coefficient should not be increased above 0.90.

The equation for calculating rainfall intensity is:

$$\mathbf{I = m / (T_c)^n}$$

where: **I** = Rainfall intensity, in inches per hour

$\mathbf{T_c}$ = Time of concentration, in minutes; and

m *and* **n** = rainfall intensity coefficients, from Table 4.7.2 for selected cities in eastern Washington; these coefficients have been determined for all major cities for the 2-, 10-, 25-, 50-, and 100-year mean recurrence intervals (MRI) based on NOAA Atlas 2.

4.7.2 Time of Concentration for Rational Method

If rainfall is applied at a constant rate over a drainage basin, it would eventually produce a constant peak rate of runoff. The amount of time that passes from the moment that the constant rainfall begins to the moment that the constant rate of runoff begins is called the time of concentration. This is the time required for the surface runoff to flow from the most hydraulically remote part of the drainage basin to the location of concern.

Actual precipitation does not fall at a constant rate. A precipitation event will generally begin with low rainfall intensity and then, sometimes very quickly, build to peak intensity, and eventually taper down to no rainfall. Because rainfall intensity is variable, the time of concentration is included in the rational method so that the designer can determine the proper rainfall intensity to apply across the basin. The intensity that should be used for design purposes is the highest intensity that will occur with the entire basin contributing flow to the location where the designer is interested in knowing the flow rate. It is important to note that this may be a much lower intensity than the absolute maximum intensity. The reason is that it often takes several minutes before the entire basin is contributing flow but the absolute maximum intensity lasts for a much shorter time so the rainfall intensity that creates the greatest runoff is less than the maximum by the time the entire basin is contributing flow.

Most drainage basins will consist of different types of ground covers and conveyance systems that flow must pass over or through. These are referred to as flow segments. It is common for a basin to have flow segments that are overland flow and flow segments that are open channel flow. Urban drainage basins often have flow segments that are flow through a storm drain pipe in addition to the other two types. A travel time (the amount of time required for flow to move through a flow segment) must be computed for each flow segment. The time of concentration is equal to the sum of all the flow segment travel times.

For a few drainage areas, a unique situation occurs where the time of concentration that produces the largest amount of runoff is less than the time of concentration for the entire basin. This can occur when two or more sub-basins have dramatically different types of cover (i.e., different runoff coefficients). The most common case would be a large paved area together with a long narrow strip of natural area. In this case, the designer should check the runoff produced by the paved area alone to determine if this scenario would cause a greater peak runoff rate than the peak runoff rate produced when both land segments are contributing flow. The scenario that produces the greatest runoff should be used, even if the entire basin is not contributing flow to this runoff.

The procedure described below for determining the time of concentration for overland flow was developed by the United States Natural Resources Conservation Service (formerly known as the Soil Conservation Service). It is sensitive to slope, type of ground cover, and the size of channel. The designer should never use a time of concentration less than 5 minutes. The time of concentration can be calculated as follows:

$$\mathbf{T_c = T_{t1} + T_{t2} + \ldots + T_{tn}}$$

using:

$$\mathbf{T_t = L / (k * (S)^{0.5})} \quad \textit{or} \quad \mathbf{T_t = L^{1.5} / (k * (\Delta H)^{0.5})}$$

where: $\mathbf{T_c}$ = Time of concentration, in minutes
$\mathbf{T_t}$ = Travel time of flow segment, in minutes
L = Length of segment, in feet
k = Ground cover coefficient from Table 4.7.3, in feet/minute
S = Slope of segment, in feet/feet
ΔH = Change in elevation of segment, in feet

Table 4.7.1 Values of runoff coefficient "C" for use in Rational Method with return intervals of 10 years or less.
See text section 4.7.1 for use with greater return intervals.

COVER	FLAT	ROLLING 2% - 10%	HILLY OVER 10%
Pavement and Roofs	0.90	0.90	0.90
Earth Shoulders	0.50	0.50	0.50
Drives and Walks	0.75	0.80	0.85
Gravel Pavement	0.50	0.55	0.60
City Business Areas	0.80	0.85	0.85
Suburban Residential*	0.25	0.35	0.40
Single Family Residential*	0.30	0.40	0.50
Lawns, Sandy Soil	0.10	0.15	0.20
Lawn, Heavy Soil	0.17	0.22	0.35
Grass Shoulders	0.25	0.25	0.25
Side Slopes, Earth	0.60	0.60	0.60
Side Slopes, Turf	0.30	0.30	0.30
Median Areas, Turf	0.25	0.30	0.30
Cultivated Land, Clay and Loam	0.50	0.55	0.60
Cultivated Land, Sand and Gravel	0.25	0.30	0.35
Industrial Areas, Light	0.50	0.70	0.80
Industrial Areas, Heavy	0.60	0.80	0.90
Parks and Cemeteries	0.10	0.15	0.25
Playgrounds	0.20	0.25	0.30
Woodland and Forests	0.10	0.15	0.20
Meadows and Pasture Land	0.25	0.30	0.35
Pasture with Frozen Ground	0.40	0.45	0.50

Source: WSDOT Hydraulics Manual, January 1997

Table 4.7.2 Values of rainfall coefficients m and n for selected cities

Location	2-Year MRI		10-Year MRI		25-Year MRI		50-Year MRI		100-Year MRI	
	m	n	m	n	m	n	m	n	m	n
Clarkston and Colfax	5.02	0.628	8.24	0.635	10.07	0.638	11.45	0.639	12.81	0.639
Colville	3.48	0.558	6.98	0.610	9.07	0.626	10.65	0.635	12.26	0.642
Ellensburg	2.89	0.590	7.00	0.649	9.43	0.664	11.30	0.672	13.18	0.678
Leavenworth	3.04	0.530	5.62	0.575	7.94	0.594	9.75	0.606	11.08	0.611
Moses Lake	2.61	0.583	6.99	0.655	9.58	0.671	11.61	0.681	13.63	0.688
Omak	3.04	0.583	6.63	0.633	8.74	0.647	10.35	0.654	11.97	0.660
Pasco and Kennewick	2.89	0.590	7.00	0.649	9.43	0.664	11.30	0.672	13.18	0.678
Snoqualmie Pass	3.61	0.417	6.56	0.459	7.72	0.459	8.78	0.461	10.21	0.476
Spokane	3.47	0.556	6.98	0.609	9.09	0.626	10.68	0.635	12.33	0.643
Stevens Pass	4.73	0.462	8.19	0.500	8.53	0.484	10.61	0.499	12.45	0.513
Walla Walla	3.33	0.569	7.30	0.627	9.67	0.645	11.45	0.653	13.28	0.660
Wenatchee	3.15	0.535	6.19	0.579	7.94	0.592	9.32	0.600	10.68	0.605
Yakima	3.86	0.608	7.37	0.644	9.40	0.654	10.93	0.659	12.47	0.663

Source: WSDOT Hydraulics Manual, January 1997 *Note: MRI = Mean Recurrence Interval*

Table 4.7.3 Values of ground cover coefficient k

Cover or channel type		k
Forest with heavy ground cover		150
Minimum tillage cultivation		280
Short pasture grass or lawn		420
Nearly bare ground		600
Small roadside ditch w/grass		900
Paved area		1,200
Gutter flow	4 in. deep	1,500
	6 in. deep	2,400
	8 in. deep	3,100
Storm sewer	12 in. diameter	3,000
	18 in. diameter	3,900
	24 in. diameter	4,700
Open channel flow (n = 0.040)	1 ft. deep	1,100
in a narrow channel (w/d = 1)	2 ft. deep	1,800
	4 ft. deep	2,800
Open channel flow (n = 0.040)	1 ft. deep	2,000
in a wide channel (w/d = 9)	2 ft. deep	3,100
	4 ft. deep	5,000

Source: WSDOT Hydraulics Manual, January 1997

Appendix 4A – Background Information on Design Storms and Selected Modeling Methods

As an early step in the process of developing a technical stormwater manual, short- and long-duration design storms were identified for eastern Washington by MGS Engineering Consultants at the request of to the Eastern Washington Stormwater Management Project Steering Committee. Questions were raised by some members of the Manual Subcommittee and during the public review and comment period on the first draft of the manual concerning the practical application and reliability of using the long-duration design storms as input for commonly used modeling methods and software. For the final draft version of the Manual, subsequent work by Harper Houf Righellis, Inc. was done at the request of the Eastern Washington Stormwater Management Project Manual Subcommittee and Technical Advisory Group. Harper Houf Righellis, Inc. reviewed the work done by MGS Engineering Consultants and recommended appropriate modeling approaches for use by the general engineering and project design community.

This appendix contains a summary description of the work done by both MGS Engineering Consultants (Section 4.A.1) and Harper Houf Righellis, Inc. (Section 4.A.2).

Appendices 4B and 4C provide additional detailed information about the short-and long-duration design storms: the precipitation data used to identify the four climatic regions of eastern Washington and generate the storms; and the resulting 72-hour, two-peak hyetographs for each of the four regions.

The 72-hour long-duration hyetographs published Appendix 4C are not currently recommended for direct use. There is concern that the single event hydrograph methods do not produce realistic results when using multiple peak hyetographs. In the SCS method, the initial abstraction (loss) is computed from the first contribution of rainfall with no accounting for the dry period between the two hyetographs to allow for initial abstraction again. This produces greater peak flows and runoff volumes than would otherwise be computed using just the second hyetograph, even while the first hyetograph is not sufficient to generate direct runoff or substantially increase soil moisture present at the start of the second hyetograph.

Updated information on modeling methods and input data will be posted on the Department of Ecology's website as it becomes available.

4A-1 Development of Short- and Long-Duration Design Storms for Eastern Washington

by MGS Engineering Consultants

Overview of Storm Types

There are two storm types of interest for stormwater analyses in eastern Washington. Short-duration thunderstorms can occur in the late spring through early fall seasons and are characterized by high intensities for short periods of time over localized areas. These types of storms can produce high rates of runoff and flash-flooding and are important where flood peak discharge and/or erosion are design considerations.

Long-duration general storms can occur at anytime of the year, but are more common in the late fall through winter period, and in the late spring and early summer periods. General storms in eastern Washington are characterized by sequences of storm activity and intervening dry periods, often occurring over several days. Low to moderate intensity precipitation is typical during the periods of storm activity. These types of events can produce floods with large runoff volumes and moderate peak discharge. The runoff volume can be augmented by snowmelt when precipitation falls on snow during winter and early spring storms. These types of storm events are important where both runoff volume and peak discharge are design considerations.

Design storms are constructed utilizing two components: a precipitation magnitude for a specified duration and a dimensionless storm pattern. The precipitation magnitude for the specified duration is determined based on the desired level of service (return period of the storm, years) and is used to scale the dimensionless storm pattern to produce the design storm. Specifically, the 2-hour precipitation amount for a selected return period is used for scaling the short-duration thunderstorm. The 24-hour precipitation amount for a selected return period is used for scaling the long-duration general storm.

This appendix provides information on the methods and data that were used for analysis and development of design storms for both short-duration thunderstorms and long-duration general storms. The dimensionless storm patterns for the short-duration thunderstorm and long-duration general storm were developed from analyses of historical storms and contain storm characteristics that are representative of the conditions frequently observed in significant storms.

Climatic Regions

Eastern Washington has been divided into four climatic regions to reflect differences in storm characteristics and the seasonality of storms. The four climatic regions (see Figure 4.3.1) include:

Region 1 – East Slopes of Cascade Mountains

This region is comprised of mountain areas on the east slopes of the Cascade Mountains. It is bounded to the west by the Cascade crest and bounded to the east by a generalized contour line of 16-inches mean annual precipitation.

Region 2 – Central Basin

The Central Basin region is comprised of the Columbia Basin and adjacent low elevation areas in central Washington. It is bounded to the west by the generalized contour line of 16-inches mean annual precipitation that forms the east slopes of the Cascade Mountains, and bounded to the north and east by the contour line of 14-inches mean annual precipitation. Many of the larger cities in eastern Washington are in this region including: Ellensburg, Kennewick, Moses Lake, Pasco, Richland, Wenatchee, and Yakima.

Region 3 – Okanogan, Spokane, Palouse

This region is comprised of inter-mountain areas and includes areas near Okanogan, Spokane, and the Palouse. It is bounded to the west by the east slopes of the Cascade Mountains and the Central Basin, bounded to the northeast by the Kettle River Range and Selkirk Mountains, and bounded to the southeast by the Blue Mountains. It generally occupies an area with mean annual precipitation ranging from 14-inches to 22-inches.

Region 4 – Northeastern Mountains and Blue Mountains

This region is comprised of mountain areas in the easternmost part of Washington State. It includes portions of the Kettle River Range and Selkirk Mountains in the northeast, and includes the Blue Mountains in the southeast corner of eastern Washington. Mean annual precipitation ranges from a minimum of 22-inches to over 60-inches. The western boundary of this region is a generalized contour line of 22-inches mean annual precipitation.

Seasonality of Storms

Information on the seasonality of storms is useful in providing information for selection of antecedent conditions to be used with the design storms for rainfall-runoff modeling at undeveloped sites.

Short-duration thunderstorms are warm season events that occur from late spring through early fall throughout eastern Washington (Figure 4A.1). Antecedent conditions for rainfall-runoff modeling of thunderstorms should be selected consistent with the conditions expected at the time of year when thunderstorms have historically occurred.

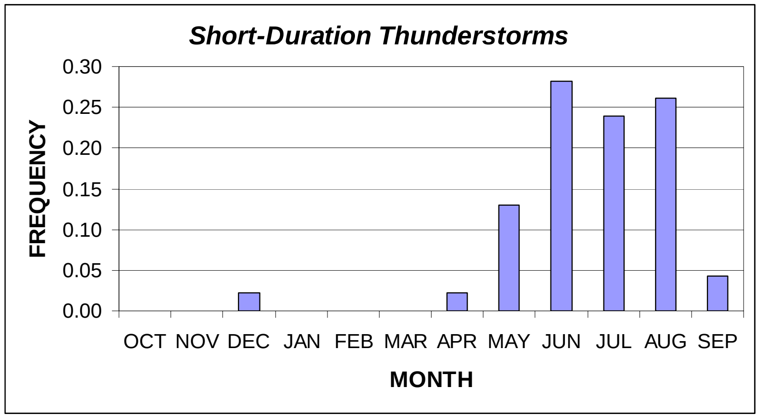


Figure 4A.1 – Seasonality of Short-Duration Thunderstorms in Eastern Washington

The seasonality of long-duration general storms varies across eastern Washington. General storms occur in late fall and winter on the east slopes of the Cascade Mountains (Figure 4A-2a) and are generally associated with concurrent storm activity in western Washington. In contrast, general storms in the more eastern climatic regions may or may not be associated with concurrent storms in western Washington. Long-duration general storms occur in both the cool and warm seasons in the Central Basin, Okanogan, Spokane, and Palouse regions. The storm seasons are reasonably well defined with more frequent storm activity from fall through early spring, and from late spring through early summer (Figure 4A-2b). The seasonality of long-duration general storms in the eastern mountain areas is similar to that for Climatic Regions 2 and 3, except that the winter season is dominant (Figure 4A-2c) with a greater frequency of storm events in the winter season. These seasonalities of storm occurrences should be considered when selecting antecedent conditions for rainfall-runoff modeling.

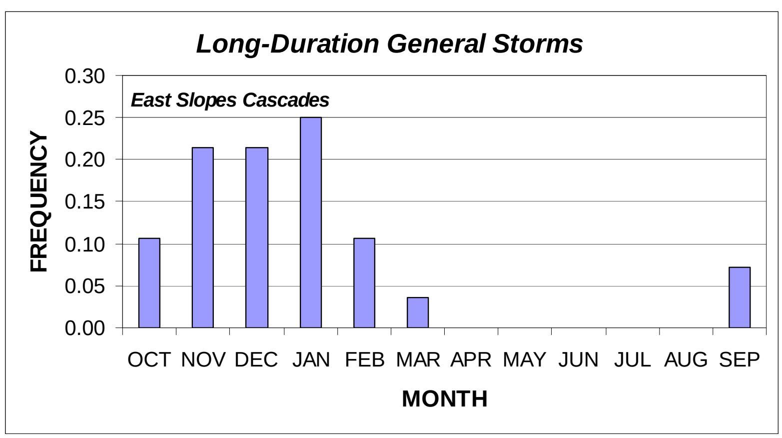


Figure 4A.2a – Seasonality of Long-Duration General Storms for the East Slopes of the Cascade Mountains

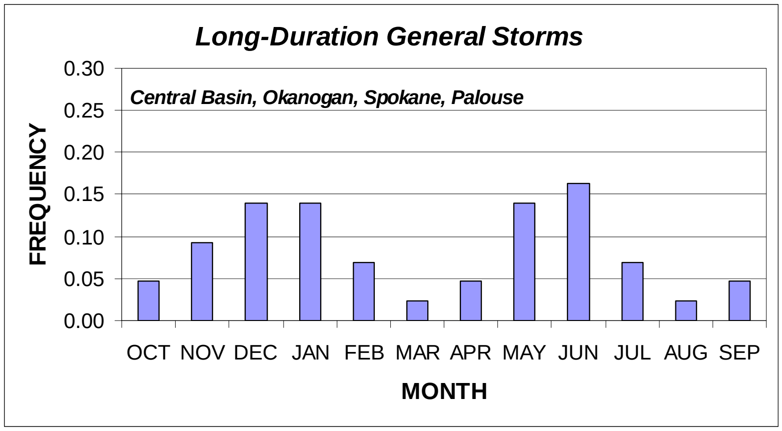


Figure 4A.2b – Seasonality of Long-Duration General Storms for the Central Basin, Okanogan, Spokane, and Palouse

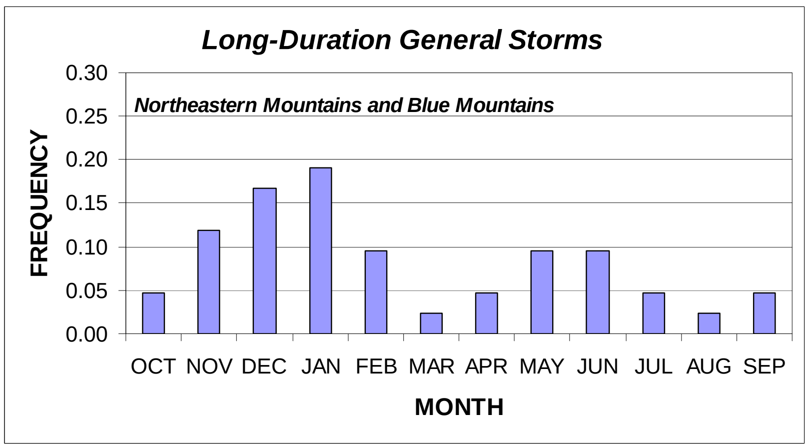


Figure 4A.2c – Seasonality of Long-Duration General Storms for the Northeastern Mountains and Blue Mountains

Dimensionless Design Storm Patterns

The temporal pattern of a design storm is important because it influences the magnitude of the flood peak discharge and runoff volume produced by the storm. Elements of the design storm that are important in rainfall-runoff modeling include: total storm volume; storm duration; maximum intensity during the storm; duration of the high intensity portion(s) of the storm; elapsed time to the high-intensity portion of the storm; and the magnitude, sequencing and temporal pattern of incremental precipitation amounts within the storm. Each of these storm characteristics was examined in the analysis of historical storms in eastern Washington. The storm characteristics were analyzed using a variety of procedures developed by the National Weather Service[3,6], Schaefer[10], and the US Geological Survey[8]. A total of 37 short-duration thunderstorms and 59 long-duration general storms that occurred in the period from 1940 to 2000 were analyzed. Attachment A contains a listing of storm dates, locations, and precipitation amounts for storms that were analyzed.

Dimensionless design storms for the short-duration thunderstorm and long-duration general storm were developed in a manner to contain storm characteristics that are representative of the conditions observed in historical storms. Specifically, mean values of storm characteristics and commonly occurring temporal patterns were used in assembling the design storm temporal patterns.

Long-Duration General Storms

Long-duration general storms in eastern Washington are associated with organized weather systems that produce low to moderate intensity precipitation over broad areas. General storms are typically comprised of sequences of storm activity and intervening dry periods, often occurring over several days. Each of these important characteristics is preserved in the long-duration dimensionless storm patterns.

While many of the characteristics of general storms are similar throughout eastern Washington, some storm characteristics vary by climatic region. For example, in mountain areas, the duration of precipitation is longer and the length of intervening dry periods is shorter, relative to that in the Central Basin. Thus, separate long-duration design storm patterns were needed for each climatic region.

An example of a scaled long-duration design storm is shown in Figure 4A-3, which was obtained by scaling (multiplying) the incremental ordinates of the dimensionless design storm (see Table 4.2.6) by a 24-hour precipitation value of 0.82-inches. Differences in temporal patterns between the four climatic regions can be seen in Figures 4B-1 through 4B-4, which compare long-duration water quality design storms for the four climatic regions.

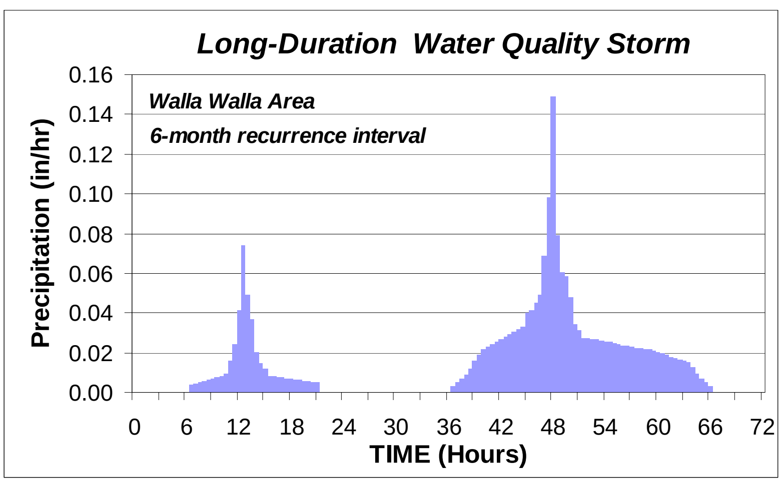


Figure 4A.3 – Example Long-Duration Design Storm

Short-Duration Thunderstorms

Short-duration thunderstorms are characterized by very high-intensity rainfall occurring over isolated areas. The duration of the high-intensity portion of the storm may last from 5 minutes to 30 minutes with a total duration typically ranging from less than an hour to several hours. These storms are convective events, commonly occurring in the late afternoon and early-evening hours in the summer where atmospheric instabilities are often driven by solar heating. They are frequently accompanied by lightning and thunder.

Analysis of historical storms indicates that short-duration thunderstorms have similar characteristics throughout eastern Washington. Therefore, one dimensionless design storm pattern is applicable to all four climatic regions. An example of a scaled short-duration design storm is shown in Figure 4A-4, which was obtained by scaling (multiplying) the incremental ordinates of the dimensionless design storm (see Table 4.2.1) by a 2-hour precipitation value of 0.50-inches.

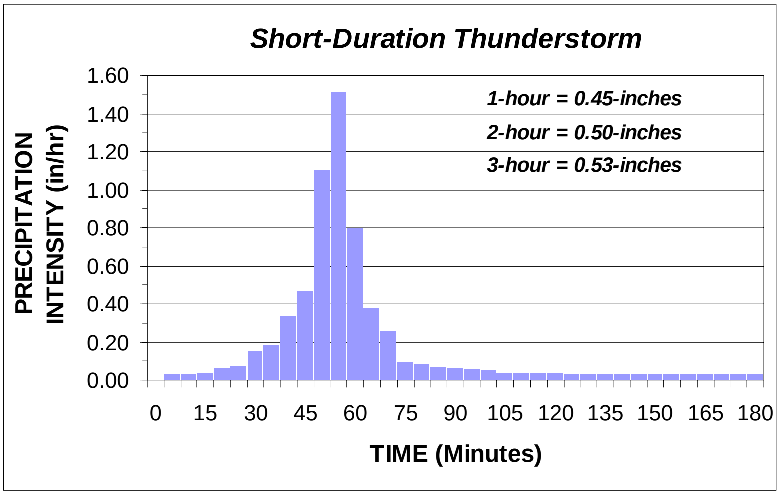


Figure 4A.4 – Example Short-Duration Design Storm

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4A-2 Review of Design Storms and Identification of Best Rainfall-Runoff Modeling Approaches for Eastern Washington

by Harper Houf Righellis, Inc.

Overview

The best available modeling approaches for using short- and long-duration design storms to size runoff treatment and flow control facilities in eastern Washington were identified and recommended in a concurrent effort. A ‘big picture’ approach was implemented and three storm types were reviewed:

- Short-Duration Storm (3 hour), intended to represent a summer thundershower.
- SCS Type II Storm (24 hour), the standard storm pattern established by the Soil Conservation Service for Eastern Washington. This is not the only storm pattern that can occur. It is the storm pattern that was designated in an era when sizing conveyance facilities (pipes, culverts, channels, and bridges) was a primary consideration and using that storm type produced the maximum peak flow rate.
- Long-Duration Storm (72 hour), intended to represent a winter or spring rainfall.

Review of the Short- and Long-Duration Design Storms

The design storms (short-duration and long-duration) developed by MGS Engineering Consultants appear appropriate in temporal pattern. The short-duration and SCS Type II storms hyetographs are common patterns utilized in arid regions. They are patterns characterized by intense rainfall over relatively short periods within their duration.

The rainfall distributions of the four regional long-duration storm hyetographs do not appear like the majority of the 57 gaged precipitation events used to create the four hyetographs. The gauged multiple peaks appear random. They vary in relative size from small to large, large to small, and sometimes similar. The spacing between peaks varies significantly. From a macro pattern perspective, the long-duration storm hyetographs appear appropriate, but implementation is a concern. Event-based runoff modeling is time dependent, thus hyetograph shape is an important parameter.

The design storms developed by MGS Engineering Consultants appear appropriate in intensities. The precipitation maps and adjustment equations are reasonable.

Identification of Best Rainfall-Runoff Modeling Approaches for Eastern Washington

There are a variety of computational methods available for computing runoff volumes and peak flow rates. Literature other than the work prepared by and cited by MGS Engineering Consultants appears non-existent for arid region long-duration storms. As MGS Engineering Consultants concluded: “Accuracy of uncalibrated runoff estimation methods is generally poor for undeveloped sites in arid and semi-arid environments. Without runoff data for verification, it is not possible to say which of the off-the-shelf runoff estimation methods would likely yield the more accurate results.”

Potential methods are Exponential Loss, Green-Ampt, Holtan, Initial Abstraction and Uniform Loss Rate, Soil Moisture Accounting, Hydrological Simulation Program--Fortran (HSPF), Natural Resources Conservation Service (NRCS) Runoff Curve Number Method, Rational Method, and Regression Equations. Many of these methods could be appropriate for long-duration runoff modeling if calibrated. MGS Engineering Consultants recommended: “The selection of runoff estimation methods should be made from commonly used methods that are readily available in computer programs for computation of runoff hydrographs.”

The above list of commonly used methods is broader than what may be commonly used by design engineers who are not hydrologic specialists. The methods most commonly used by regulatory agencies, design professionals, and software vendors are the SCS Method (NRCS Runoff Curve Number Method), Rational Method, and Regression Equations. Only commonly used methods should be considered until quality data can be collected and rainfall-runoff calibration efforts performed.

With commonly used methods, the expertise of regulatory agencies, design professionals, and software vendors offer the best opportunity to use reasonable input values and produce reasonable output. Thus even though not technically calibrated, results that meet the standard of care for the industry are more likely using common uncalibrated methods than uncommon uncalibrated methods.

Of the three commonly used methods listed above (SCS Method, Rational Method, and Regression Equations), only the SCS Curve Number Method is recommended for computing flow rates and runoff volumes for long-duration storms. The Rational Method is a good method for computing peak flow rates of small urban basins but has no capability to determine reasonable hydrographs and runoff volumes. Regression Equations require quality-measured data to create meaningful regression equations, but necessary data are lacking; peak flow rate determination is the common use of regression equations as runoff volume regression equations appear non-existent.

The SCS Method is commonly used for small and large basins, though method origins are from large rural basins. The engineering community has experience implementing this method.

Discussion and Recommendation of Modified SCS Modeling Approach

Short-Duration Storm (3 hour) and SCS Type II Storm (24 hour)
The short-duration 3-hour storm and the SCS Type II 24-hour storm hyetographs can be directly modeled by readily available hydrologic modeling software and produce intended results.

Long-Duration Storm (72 hour)
The multiple-peak long-duration storm can also be directly modeled by readily available hydrologic modeling software, but does not necessarily produce intended results. NRCS staff has verbally stated that the SCS Method should not be applied to multiple-peak hyetographs. The caution may have been due merely to an unintended use or due to possible computational inaccuracies, but the latter appears to be the case.

With this limitation, another approach is necessary to model the long-duration storm hyetographs. Two key characteristics are apparent from the multiple-peak long-duration hyetographs.

- The first portion of the four regional hyetographs is small compared to the second portion. The first portion of the hyetograph is 16% to 25% of the total hyetograph, depending on the region. For most eastern Washington 72-hour precipitation amounts, the precipitation amount in the first portion hyetograph is diminutive.
- The period of no precipitation between the end of the first portion and beginning of the second portion of the hyetograph ranges from about 12 to 18 hours, depending on the region.

These two characteristics result in hydrographs that have no flow for the entire time between the two hyetographs and sometimes no flow during the first hyetograph. This means there is no compelling reason to directly model the first portion.

If only the second portion needs to be modeled, it may be possible to substitute another standard storm distribution: the SCS Type IA storm pattern of the coastal region of the state where winter rainfall originates. Figure 4A.5 shows only the second portion of the hyetographs for the four regional long-duration storms as cumulative precipitation and the SCS Type IA and Type II 24-hour storms in order to make a visual comparison.

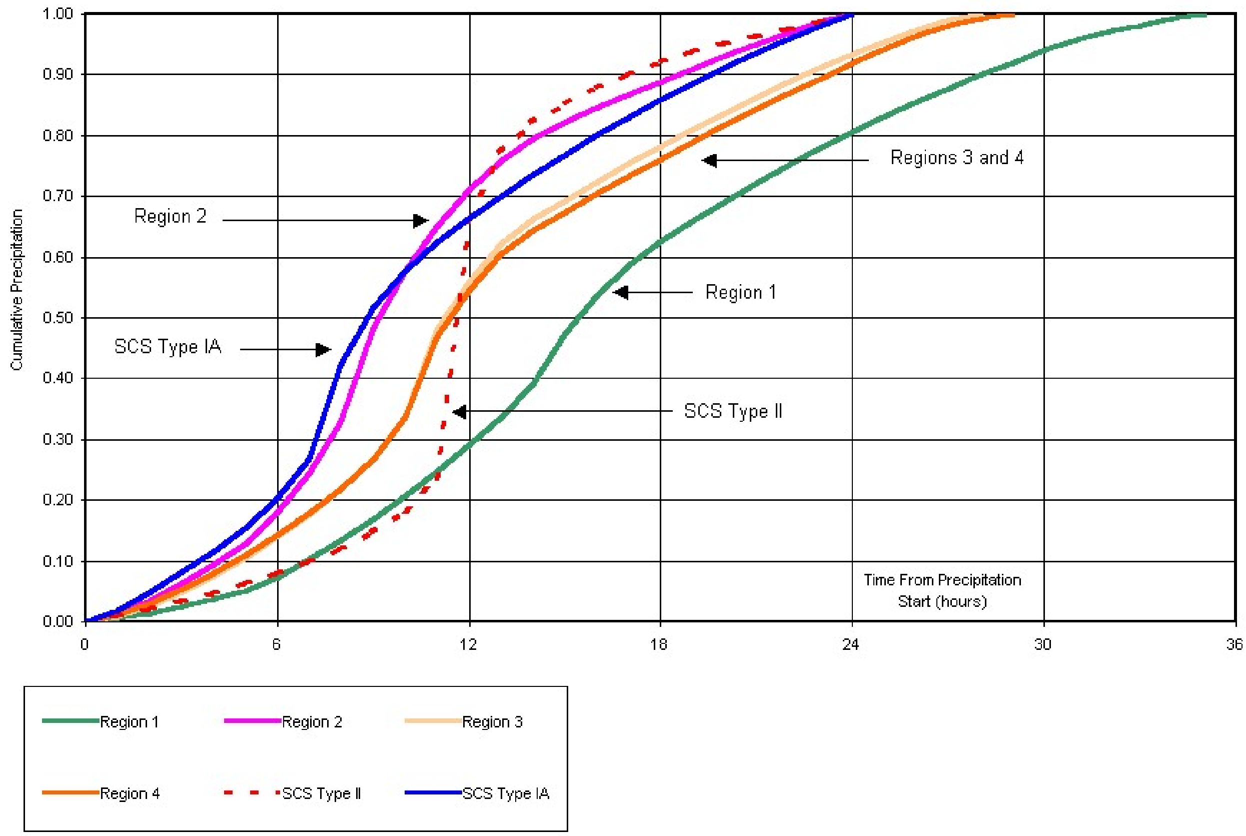

Figure 4A.5 – Standard and Regional Storm Distribution Curves on a Unit Basis

The Type IA storm is similar in shape to the second portion of all four regional long-duration storms. With this similarity, the Type IA may produce acceptable results without the added complexity. Its 24-hour duration allows for easy use of the built-in storm pattern feature of most SCS Method software. This reduces potential for computational errors due to incorrect implementation of unique duration hyetographs.

Actual duration analysis provides computations that more directly reflect the second portion of the long-duration storm hyetographs, but those durations are not precise, they are statistical representations. The following table shows the key comparisons to the Type 1A storm.

Second Portion of Long-Duration Hyetograph	Region 1	Region 2	Region 3	Region 4
Duration (hours)	35	24	28	29
Duration as Ratio of 24 Hours	1.46	1.00	1.16	1.21
Precipitation as Ratio of 24-Hour Precipitation	1.16	1.00	1.06	1.07

Region 1 could be considered for 35-hour duration and 1.16 x 24-hour precipitation storm analysis. 16% more precipitation spread over 46% more time should produce less peak flow but more runoff volume than the Type IA storm. Many of the differences compared to the Type IA storm is in the waning hours of the hyetograph, thus would have less impact than might be expected. The second portions of the long-duration hyetographs for Regions 2, 3, and 4 show no or only minor variation from SCS Type IA 24-hour storm, thus use of 24-hour storm is sufficiently accurate.

Short-Duration Storm (3 hour) and SCS Type II Storm (24 hour)
Modeling of the short-duration three-hour storm and the SCS Type II 24-hour storm are to be per standard methods for those hyetographs.

Long-Duration Storm (72 hour)
The recommended approach for modeling the long-duration storm is as follows.

- Rainfall Modeling:
  Emulate only the second portion of the long-duration storm hyetograph, but account for the first portion by adjusting antecedent moisture conditions.
- Rainfall Distribution:
  Use the SCS Type IA 24-hour storm. This provides the simplest modeling approach and reduces the chance for error by implementing a non-standard hyetograph. If an agency or local jurisdiction prefers the long-duration distributions, the second portion of the long-duration storm hyetograph can be implemented instead.
- Rainfall Intensity:
  Use 24-hour intensity if using the SCS Type IA storm. If using the second portion of the long-duration storm hyetograph, use the precipitation ratio in the table above.
- Curve Numbers:
  Adjust Curve Numbers to account for saturation conditions due to first portion of hyetograph that is not directly modeled. Engineering analysis and judgment is needed for Curve Number adjustment depending on soil characteristics, surface conditions, and first-portion precipitation amount.

Sensitivity Analysis

The primary concern regarding the SCS Method that arose in this study effort was the implementation of the multi-peak hyetographs. To test the concern, HEC-HMS (Hydrologic Engineering Center – Hydrologic Modeling System) was used to compute hydrographs. Three 25-year event hyetographs were modeled for an eight-acre basin with four basin coverage conditions.

For the 72-hour storm, as the initial loss rate decreased, runoff was generated earlier in the second hyetograph than in the SCS Type IA and second-portion only storm hyetographs. This means there was less initial abstraction (loss) computed in the more critical portion of the 72-hour hyetograph than the other storms. This is counterintuitive as the bulk of the 0.55 inches first-portion hyetograph rainfall occurs 24 hours prior to the start of the second hyetograph, thus there should be opportunity for the entire initial loss to occur again at the start of the second hyetograph.

This initial loss computational difference and the impact it may have on second-portion hydrograph flow rates supports the NRCS contention regarding the modeling of multiple peak hyetographs. The peak flow rates computed in the multi-peak long-duration 72-hour storm did not match well with the peak flow rates computed from the other two hyetographs.

Further Recommendations

A future effort of rainfall-runoff data collection and modeling correlation should be undertaken. This will improve the best available science beyond what exists today. Precipitation gages that can measure in small time increments should be placed within drainage basins where runoff flows can be measured in similar small time increments. To be effective, this data collection effort should include broad ranges of drainage basins based on total annual precipitation, elevation, grades, soils types, development types, and degree of development.

Upon storm type segregation, further data analysis should include determination of effective modeling parameters such as lag times and SCS Curve Numbers and comparing them to values commonly used.

Appendix 4B – Historical Storms Used to Develop Design Storms in Eastern Washington

Long-Duration General Storms

Region 1 – Cascade Mountains

PRECIPITATION STATION	STORM DATE	PRECIPITATION 24-HOUR (in)	PRECIPITATION 72-HOUR (in)
Diablo Dam	24-Oct-1945	6.42	9.23
Underwood	11-Dec-1946	4.04	7.27
Hood River Exp Station	6-Jan-1948	3.33	4.53
Diablo Dam	16-Feb-1949	8.12	9.64
Diablo Dam	9-Feb-1951	6.47	12.99
Satus Pass	24-Nov-1960	3.12	4.46
Lucerne 2NNW	19-Nov-1962	3.05	3.45
Mazama	27-Feb-1972	3.80	5.97
Mount Adams RS	13-Jan-1973	6.00	11.39
Satus Pass	15-Jan-1974	3.60	6.05
Lucerne 2NNW	1-Dec-1975	3.17	5.99
Satus Pass	13-Dec-1977	3.30	5.02
Mazama	12-Jan-1980	3.20	3.62
Stehekin 4NW	23-Jan-1982	5.00	6.80
Stevens Pass	3-Dec-1982	6.50	7.40
Carson Fish Hatch	9-Dec-1987	6.20	7.90
Lake Wenatchee	9-Jan-1990	5.30	7.60
Easton	22-Nov-1990	6.40	10.20
Glenwood	27-Oct-1994	3.80	4.10
Easton	8-Feb-1996	4.10	8.90
Glenwood	28-Dec-1998	3.70	4.70

Region 2 – Central Basin

PRECIPITATION STATION	STORM DATE	PRECIPITATION 24-HOUR (in)	PRECIPITATION 72-HOUR (in)
Lind 3NE	25-Jun-1942	1.53	1.77
Harrington 4ENE	21-Sep-1945	1.52	2.10
Coulee Dam 1SW	28-May-1948	1.66	1.74
Harrington 4ENE	25-Sep-1948	1.51	1.65
Centerville	19-Jan-1953	2.36	2.76
Naches 10NW	14-Jan-1956	1.43	1.60
McNary Dam	2-Oct-1957	3.15	3.17
Yakima	24-Dec-1964	1.40	2.83
Harrington 1NW	23-Dec-1966	1.12	1.28
Ellensburg	4-Dec-1974	1.30	2.00
Chief Joe Dam	18-Sep-1986	1.50	1.70
Wenatchee	10-Dec-1987	1.77	1.82
Yakima	19-Nov-1996	1.40	1.57

Region 3 – Okanogan/Spokane/Palouse

PRECIPITATION STATION	STORM DATE	PRECIPITATION 24-HOUR (in)	PRECIPITATION 72-HOUR (in)
Pullman 2NW	15-Sep-1947	2.10	2.60
Oroville	16-Nov-1950	1.96	2.04
Spokane WSO AP	18-Dec-1951	1.58	1.67
Spokane WSO AP	25-Nov-1960	1.41	1.86
Pullman 2NW	22-Nov-1961	1.96	2.52
Dixie 4SE	23-Nov-1964	2.70	2.92
Dayton 9SE	22-Dec-1964	3.01	4.70
Dayton 9SE	2-Jan-1966	2.53	3.69
Moscow 5NE ID	23-Dec-1972	1.80	2.70
Moscow 5NE ID	11-Nov-1973	1.70	2.90
Colville Airport	16-Nov-1973	1.55	1.98
Walla Walla WSO	14-Oct-1980	3.08	3.63
Moscow 5NE ID	9-Feb-1996	1.50	3.20
Whitman Mission	19-Nov-1996	2.00	2.40
Ola ID	27-Dec-1996	3.10	5.00
Republic	27-May-1998	2.50	2.80
Spokane WSO AP	13-Apr-2000	1.53	1.73

Region 4 – Northeastern Mountains and Blue Mountains

PRECIPITATION STATION	STORM DATE	PRECIPITATION 24-HOUR (in)	PRECIPITATION 72-HOUR (in)
Bonners Ferry 1SW	18-Nov-1946	2.78	4.09
Pullman 2NW	15-Sep-1947	2.10	2.60
Pullman 2NW	22-Nov-1961	1.96	2.52
Dayton 9SE	22-Dec-1964	3.01	4.70
Dayton 9SE	2-Jan-1966	2.53	3.69
Moscow 5NE ID	23-Dec-1972	1.80	2.70
Moscow 5NE ID	11-Nov-1973	1.70	2.90
Colville Airport	16-Nov-1973	1.55	1.98
Coeur D Alene RS	15-Jan-1974	1.90	3.70
Dworshak Fish Hatch ID	2-Dec-1977	2.30	2.40
Plummer 3WSW ID	25-Dec-1980	2.10	2.80
Boundary Switchyard	15-Feb-1986	3.10	3.19
Boundary Switchyard	4-Jan-1989	2.30	2.50
Moscow 5NE ID	9-Feb-1996	1.50	3.20
Ola ID	27-Dec-1996	3.10	5.00
Northport	27-May-1998	2.40	2.80

Short-Duration Thunderstorms

All Regions

PRECIPITATION STATION	CLIMATIC REGION	STORM DATE	PRECIPITATION 1-HOUR (in)	PRECIPITATION 2-HOUR (in)
Ellensburg	2	12-May-1943	0.31	0.62
Dayton 1WSW	3	8-Jul-1946	0.78	0.79
Sunnyside	2	7-Jun-1947	1.62	1.62
Oroville	3	16-Jun-1947	1.19	1.25
Methow	2	17-Jun-1950	0.89	0.89
Wilson Creek	2	18-Jun-1950	1.50	1.50
Colville	4	19-Jul-1950	0.92	1.00
Wilson Creek	2	24-Jul-1950	0.80	0.80
Wenatchee Exp Station	2	10-Aug-1952	1.29	1.29
Colville	4	6-Jul-1956	0.81	0.82
Naches 10NW	2	5-May-1957	0.70	0.90
Republic RS	3	5-Jul-1958	1.10	1.10
Methow	2	8-Jul-1958	1.33	1.33
Republic RS	3	9-Aug-1962	1.17	1.26
Pomeroy	3	13-Sep-1966	1.12	1.12
Withrow 4WNW	2	14-Aug-1968	0.64	0.94
Walla Walla WSO	3	26-May-1971	1.64	1.75
Yakima	2	18-Aug-1975	0.70	0.98
Whitman Mission	3	5-Aug-1977	0.94	0.94
Dayton 1WSW	3	7-Jul-1978	1.20	1.20
Boundary Switchyard	4	21-May-1981	0.90	1.10
Naches 10NW	2	7-Jul-1982	1.20	1.20
Chewelah	3	20-Jul-1983	0.90	1.00
Republic RS	3	10-Aug-1983	0.90	1.50
Easton	1	26-Aug-1983	1.80	1.80
Naches 10NW	2	1-Aug-1984	0.80	0.80
Lake Wenatchee	1	11-Feb-1985	0.90	1.10
Mazama	1	16-Jul-1985	1.00	1.10
Diablo Dam	1	20-Jul-1992	0.80	1.10
Chief Joe Dam	2	23-Jul-1992	0.70	1.00
Dixie 4SE	4	7-Aug-1992	0.70	0.90
Boundary Switchyard	4	23-May-1989	1.00	1.00
Chief Joe Dam	2	9-Jul-1993	1.10	1.10
Lind 3NE	2	22-Jul-1993	1.30	1.40
Stevens Pass	1	2-Jun-1998	1.00	1.00
Northport	4	11-Jul-1998	1.10	1.10
Colville	4	3-Jun-1999	1.00	1.90

Appendix 4C – Long-Duration Storm Hyetographs for Eastern Washington

Following are graphical and tabular representations of the long-duration design storms developed by MGS Engineering Consultants.

Note that the 72-hour hyetographs are not unit hyetographs, but have maximum values equal to the ratio of the total 72-hour precipitation to the 24-hour precipitation.

See Appendix 4A for additional information and limitations in applying these hyetographs.

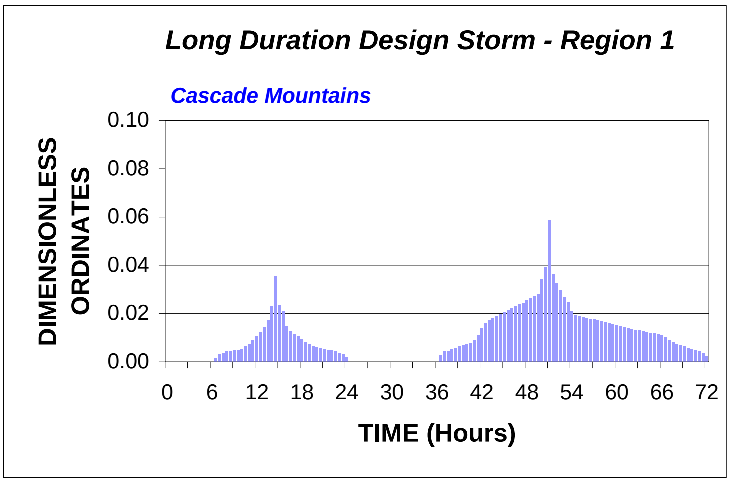

Figure 4B-1

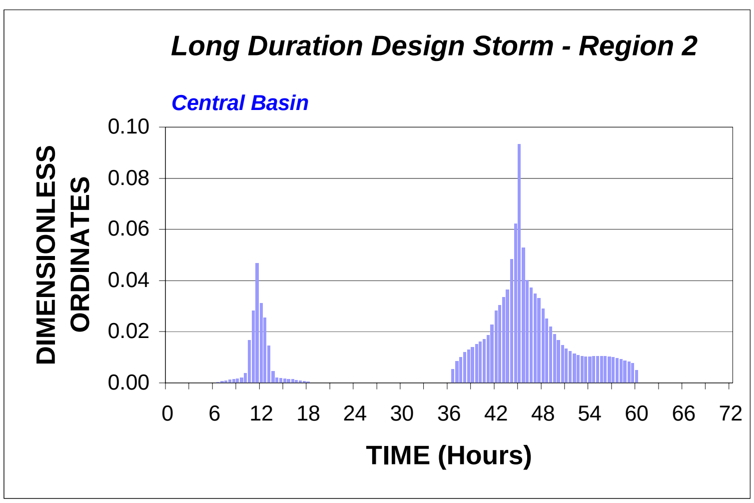

Figure 4B-2

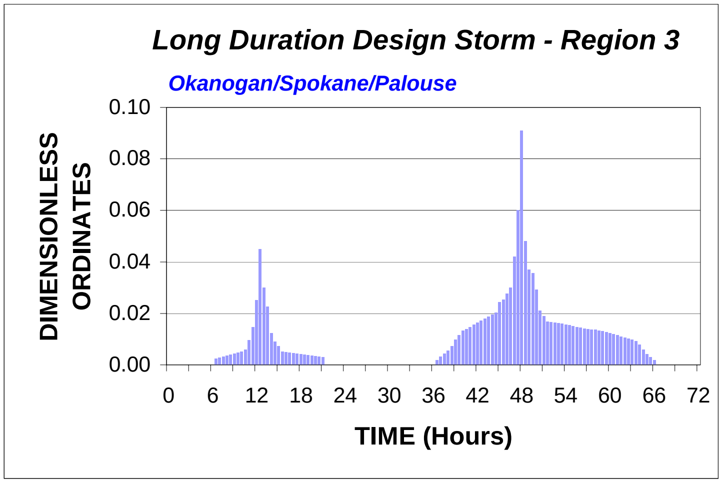

Figure 4B-3

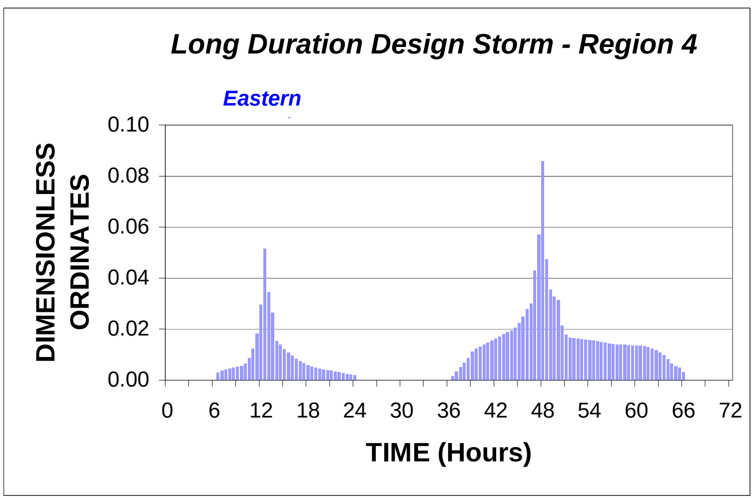

Figure 4B-4

72-Hour Long-Duration Storm Hyetograph Values for Region 1: Cascade Mountains

Note: Use 24-hour precipitation value to scale this storm hyetograph.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.00000	0.00000
0.5	0.00000	0.00000
1.0	0.00000	0.00000
1.5	0.00000	0.00000
2.0	0.00000	0.00000
2.5	0.00000	0.00000
3.0	0.00000	0.00000
3.5	0.00000	0.00000
4.0	0.00000	0.00000
4.5	0.00000	0.00000
5.0	0.00000	0.00000
5.5	0.00000	0.00000
6.0	0.00000	0.00000
6.5	0.00179	0.00179
7.0	0.00321	0.00500
7.5	0.00370	0.00870
8.0	0.00420	0.01290
8.5	0.00470	0.01760
9.0	0.00490	0.02250
9.5	0.00510	0.02760
10.0	0.00530	0.03290
10.5	0.00634	0.03924
11.0	0.00740	0.04664
11.5	0.00920	0.05584
12.0	0.01080	0.06664
12.5	0.01214	0.07878
13.0	0.01424	0.09302
13.5	0.01712	0.11014
14.0	0.02288	0.13302
14.5	0.03540	0.16842
15.0	0.02360	0.19202
15.5	0.02101	0.21303
16.0	0.01499	0.22802
16.5	0.01279	0.24081
17.0	0.01144	0.25225
17.5	0.01070	0.26295
18.0	0.00960	0.27255
18.5	0.00814	0.28069
19.0	0.00730	0.28799
19.5	0.00657	0.29456
20.0	0.00598	0.30054
20.5	0.00551	0.30605
21.0	0.00516	0.31121
21.5	0.00494	0.31615
22.0	0.00485	0.32100
22.5	0.00420	0.32520
23.0	0.00370	0.32890
23.5	0.00320	0.33210
24.0	0.00180	0.33390

Time (hours)	Incremental Rainfall	Cumulative Rainfall
24.5	0.00000	0.33390
25.0	0.00000	0.33390
25.5	0.00000	0.33390
26.0	0.00000	0.33390
26.5	0.00000	0.33390
27.0	0.00000	0.33390
27.5	0.00000	0.33390
28.0	0.00000	0.33390
28.5	0.00000	0.33390
29.0	0.00000	0.33390
29.5	0.00000	0.33390
30.0	0.00000	0.33390
30.5	0.00000	0.33390
31.0	0.00000	0.33390
31.5	0.00000	0.33390
32.0	0.00000	0.33390
32.5	0.00000	0.33390
33.0	0.00000	0.33390
33.5	0.00000	0.33390
34.0	0.00000	0.33390
34.5	0.00000	0.33390
35.0	0.00000	0.33390
35.5	0.00000	0.33390
36.0	0.00000	0.33390
36.5	0.00277	0.33667
37.0	0.00423	0.34090
37.5	0.00467	0.34557
38.0	0.00550	0.35107
38.5	0.00590	0.35697
39.0	0.00630	0.36327
39.5	0.00670	0.36997
40.0	0.00723	0.37720
40.5	0.00760	0.38480
41.0	0.00907	0.39387
41.5	0.01116	0.40503
42.0	0.01387	0.41890
42.5	0.01600	0.43490
43.0	0.01740	0.45230
43.5	0.01820	0.47050
44.0	0.01900	0.48950
44.5	0.01980	0.50930
45.0	0.02060	0.52990
45.5	0.02140	0.55130
46.0	0.02220	0.57350
46.5	0.02300	0.59650
47.0	0.02380	0.62030
47.5	0.02460	0.64490
48.0	0.02550	0.67040
48.5	0.02620	0.69660

Time (hours)	Incremental Rainfall	Cumulative Rainfall
49.0	0.02720	0.72380
49.5	0.02820	0.75200
50.0	0.03445	0.78645
50.5	0.03920	0.82565
51.0	0.05880	0.88445
51.5	0.03652	0.92097
52.0	0.03280	0.95377
52.5	0.02980	0.98357
53.0	0.02680	1.01037
53.5	0.02484	1.03521
54.0	0.02116	1.05637
54.5	0.01943	1.07580
55.0	0.01910	1.09490
55.5	0.01870	1.11360
56.0	0.01830	1.13190
56.5	0.01790	1.14980
57.0	0.01750	1.16730
57.5	0.01710	1.18440
58.0	0.01670	1.20110
58.5	0.01630	1.21740
59.0	0.01590	1.23330
59.5	0.01550	1.24880
60.0	0.01510	1.26390
60.5	0.01470	1.27860
61.0	0.01430	1.29290
61.5	0.01390	1.30680
62.0	0.01360	1.32040
62.5	0.01330	1.33370
63.0	0.01300	1.34670
63.5	0.01270	1.35940
64.0	0.01240	1.37180
64.5	0.01210	1.38390
65.0	0.01180	1.39570
65.5	0.01150	1.40720
66.0	0.01120	1.41840
66.5	0.01020	1.42860
67.0	0.00920	1.43780
67.5	0.00820	1.44600
68.0	0.00734	1.45334
68.5	0.00675	1.46009
69.0	0.00630	1.46639
69.5	0.00585	1.47224
70.0	0.00540	1.47764
70.5	0.00495	1.48259
71.0	0.00450	1.48709
71.5	0.00350	1.49059
72.0	0.00225	1.49284

72-Hour Long-Duration Storm Hyetograph Values for Region 2: Central Basin

Note: Use 24-hour precipitation value to scale this storm hyetograph.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.00000	0.00000
0.5	0.00000	0.00000
1.0	0.00000	0.00000
1.5	0.00000	0.00000
2.0	0.00000	0.00000
2.5	0.00000	0.00000
3.0	0.00000	0.00000
3.5	0.00000	0.00000
4.0	0.00000	0.00000
4.5	0.00000	0.00000
5.0	0.00000	0.00000
5.5	0.00000	0.00000
6.0	0.00000	0.00000
6.5	0.00030	0.00030
7.0	0.00060	0.00090
7.5	0.00090	0.00180
8.0	0.00120	0.00300
8.5	0.00150	0.00450
9.0	0.00180	0.00630
9.5	0.00210	0.00840
10.0	0.00394	0.01234
10.5	0.01669	0.02903
11.0	0.02831	0.05734
11.5	0.04680	0.10414
12.0	0.03120	0.13534
12.5	0.02549	0.16083
13.0	0.01451	0.17534
13.5	0.00445	0.17979
14.0	0.00202	0.18181
14.5	0.00192	0.18373
15.0	0.00172	0.18545
15.5	0.00152	0.18697
16.0	0.00132	0.18829
16.5	0.00112	0.18941
17.0	0.00092	0.19033
17.5	0.00072	0.19105
18.0	0.00052	0.19157
18.5	0.00000	0.19157
19.0	0.00000	0.19157
19.5	0.00000	0.19157
20.0	0.00000	0.19157
20.5	0.00000	0.19157
21.0	0.00000	0.19157
21.5	0.00000	0.19157
22.0	0.00000	0.19157
22.5	0.00000	0.19157
23.0	0.00000	0.19157
23.5	0.00000	0.19157
24.0	0.00000	0.19157

Time (hours)	Incremental Rainfall	Cumulative Rainfall
24.5	0.00000	0.19157
25.0	0.00000	0.19157
25.5	0.00000	0.19157
26.0	0.00000	0.19157
26.5	0.00000	0.19157
27.0	0.00000	0.19157
27.5	0.00000	0.19157
28.0	0.00000	0.19157
28.5	0.00000	0.19157
29.0	0.00000	0.19157
29.5	0.00000	0.19157
30.0	0.00000	0.19157
30.5	0.00000	0.19157
31.0	0.00000	0.19157
31.5	0.00000	0.19157
32.0	0.00000	0.19157
32.5	0.00000	0.19157
33.0	0.00000	0.19157
33.5	0.00000	0.19157
34.0	0.00000	0.19157
34.5	0.00000	0.19157
35.0	0.00000	0.19157
35.5	0.00000	0.19157
36.0	0.00000	0.19157
36.5	0.00544	0.19701
37.0	0.00856	0.20557
37.5	0.01000	0.21557
38.0	0.01200	0.22757
38.5	0.01300	0.24057
39.0	0.01400	0.25457
39.5	0.01500	0.26957
40.0	0.01600	0.28557
40.5	0.01700	0.30257
41.0	0.01869	0.32126
41.5	0.02281	0.34407
42.0	0.02832	0.37239
42.5	0.03050	0.40289
43.0	0.03350	0.43639
43.5	0.03650	0.47289
44.0	0.04842	0.52131
44.5	0.06220	0.58351
45.0	0.09330	0.67681
45.5	0.05275	0.72956
46.0	0.04025	0.76981
46.5	0.03717	0.80698
47.0	0.03483	0.84181
47.5	0.03307	0.87488
48.0	0.02893	0.90381
48.5	0.02519	0.92900

Time (hours)	Incremental Rainfall	Cumulative Rainfall
49.0	0.02189	0.95089
49.5	0.01906	0.96995
50.0	0.01670	0.98665
50.5	0.01480	1.00145
51.0	0.01336	1.01481
51.5	0.01234	1.02715
52.0	0.01156	1.03871
52.5	0.01096	1.04967
53.0	0.01054	1.06021
53.5	0.01032	1.07053
54.0	0.01028	1.08081
54.5	0.01038	1.09119
55.0	0.01046	1.10165
55.5	0.01046	1.11211
56.0	0.01040	1.12251
56.5	0.01025	1.13276
57.0	0.01004	1.14280
57.5	0.00974	1.15254
58.0	0.00926	1.16180
58.5	0.00868	1.17048
59.0	0.00832	1.17880
59.5	0.00781	1.18661
60.0	0.00500	1.19161
60.5	0.00000	1.19161
61.0	0.00000	1.19161
61.5	0.00000	1.19161
62.0	0.00000	1.19161
62.5	0.00000	1.19161
63.0	0.00000	1.19161
63.5	0.00000	1.19161
64.0	0.00000	1.19161
64.5	0.00000	1.19161
65.0	0.00000	1.19161
65.5	0.00000	1.19161
66.0	0.00000	1.19161
66.5	0.00000	1.19161
67.0	0.00000	1.19161
67.5	0.00000	1.19161
68.0	0.00000	1.19161
68.5	0.00000	1.19161
69.0	0.00000	1.19161
69.5	0.00000	1.19161
70.0	0.00000	1.19161
70.5	0.00000	1.19161
71.0	0.00000	1.19161
71.5	0.00000	1.19161
72.0	0.00000	1.19161

72-Hour Long-Duration Storm Hyetograph Values for Region 3: Okanogan, Spokane, Palouse

Note: Use 24-hour precipitation value to scale this storm hyetograph.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.00000	0.00000
0.5	0.00000	0.00000
1.0	0.00000	0.00000
1.5	0.00000	0.00000
2.0	0.00000	0.00000
2.5	0.00000	0.00000
3.0	0.00000	0.00000
3.5	0.00000	0.00000
4.0	0.00000	0.00000
4.5	0.00000	0.00000
5.0	0.00000	0.00000
5.5	0.00000	0.00000
6.0	0.00000	0.00000
6.5	0.00240	0.00240
7.0	0.00280	0.00520
7.5	0.00320	0.00840
8.0	0.00360	0.01200
8.5	0.00403	0.01603
9.0	0.00440	0.02043
9.5	0.00480	0.02523
10.0	0.00520	0.03043
10.5	0.00600	0.03643
11.0	0.00968	0.04611
11.5	0.01476	0.06087
12.0	0.02524	0.08611
12.5	0.04500	0.13111
13.0	0.03000	0.16111
13.5	0.02267	0.18378
14.0	0.01233	0.19611
14.5	0.00901	0.20512
15.0	0.00731	0.21243
15.5	0.00520	0.21763
16.0	0.00500	0.22263
16.5	0.00480	0.22743
17.0	0.00460	0.23203
17.5	0.00440	0.23643
18.0	0.00420	0.24063
18.5	0.00400	0.24463
19.0	0.00380	0.24843
19.5	0.00360	0.25203
20.0	0.00340	0.25543
20.5	0.00320	0.25863
21.0	0.00300	0.26163
21.5	0.00000	0.26163
22.0	0.00000	0.26163
22.5	0.00000	0.26163
23.0	0.00000	0.26163
23.5	0.00000	0.26163
24.0	0.00000	0.26163

Time (hours)	Incremental Rainfall	Cumulative Rainfall
24.5	0.00000	0.26163
25.0	0.00000	0.26163
25.5	0.00000	0.26163
26.0	0.00000	0.26163
26.5	0.00000	0.26163
27.0	0.00000	0.26163
27.5	0.00000	0.26163
28.0	0.00000	0.26163
28.5	0.00000	0.26163
29.0	0.00000	0.26163
29.5	0.00000	0.26163
30.0	0.00000	0.26163
30.5	0.00000	0.26163
31.0	0.00000	0.26163
31.5	0.00000	0.26163
32.0	0.00000	0.26163
32.5	0.00000	0.26163
33.0	0.00000	0.26163
33.5	0.00000	0.26163
34.0	0.00000	0.26163
34.5	0.00000	0.26163
35.0	0.00000	0.26163
35.5	0.00000	0.26163
36.0	0.00000	0.26163
36.5	0.00180	0.26343
37.0	0.00320	0.26663
37.5	0.00437	0.27100
38.0	0.00563	0.27663
38.5	0.00722	0.28385
39.0	0.00978	0.29363
39.5	0.01150	0.30513
40.0	0.01340	0.31853
40.5	0.01400	0.33253
41.0	0.01480	0.34733
41.5	0.01560	0.36293
42.0	0.01640	0.37933
42.5	0.01720	0.39653
43.0	0.01800	0.41453
43.5	0.01880	0.43333
44.0	0.01960	0.45293
44.5	0.02040	0.47333
45.0	0.02430	0.49763
45.5	0.02534	0.52297
46.0	0.02766	0.55063
46.5	0.03000	0.58063
47.0	0.04200	0.62263
47.5	0.06000	0.68263
48.0	0.09100	0.77363
48.5	0.04801	0.82164

Time (hours)	Incremental Rainfall	Cumulative Rainfall
49.0	0.03700	0.85864
49.5	0.03568	0.89432
50.0	0.02932	0.92364
50.5	0.02114	0.94478
51.0	0.01900	0.96378
51.5	0.01680	0.98058
52.0	0.01660	0.99718
52.5	0.01640	1.01358
53.0	0.01620	1.02978
53.5	0.01600	1.04578
54.0	0.01570	1.06148
54.5	0.01540	1.07688
55.0	0.01510	1.09198
55.5	0.01480	1.10678
56.0	0.01450	1.12128
56.5	0.01420	1.13548
57.0	0.01390	1.14938
57.5	0.01379	1.16317
58.0	0.01361	1.17678
58.5	0.01338	1.19016
59.0	0.01310	1.20326
59.5	0.01276	1.21602
60.0	0.01236	1.22838
60.5	0.01192	1.24030
61.0	0.01148	1.25178
61.5	0.01104	1.26282
62.0	0.01061	1.27343
62.5	0.01018	1.28361
63.0	0.00976	1.29337
63.5	0.00918	1.30255
64.0	0.00782	1.31037
64.5	0.00579	1.31616
65.0	0.00421	1.32037
65.5	0.00315	1.32352
66.0	0.00185	1.32537
66.5	0.00000	1.32537
67.0	0.00000	1.32537
67.5	0.00000	1.32537
68.0	0.00000	1.32537
68.5	0.00000	1.32537
69.0	0.00000	1.32537
69.5	0.00000	1.32537
70.0	0.00000	1.32537
70.5	0.00000	1.32537
71.0	0.00000	1.32537
71.5	0.00000	1.32537
72.0	0.00000	1.32537

72-Hour Long-Duration Storm Hyetograph Values for Region 4: Eastern Mountains

Note: Use 24-hour precipitation value to scale this storm hyetograph.

Time (hours)	Incremental Rainfall	Cumulative Rainfall
0.0	0.00000	0.00000
0.5	0.00000	0.00000
1.0	0.00000	0.00000
1.5	0.00000	0.00000
2.0	0.00000	0.00000
2.5	0.00000	0.00000
3.0	0.00000	0.00000
3.5	0.00000	0.00000
4.0	0.00000	0.00000
4.5	0.00000	0.00000
5.0	0.00000	0.00000
5.5	0.00000	0.00000
6.0	0.00000	0.00000
6.5	0.00300	0.00300
7.0	0.00390	0.00690
7.5	0.00423	0.01113
8.0	0.00456	0.01569
8.5	0.00490	0.02059
9.0	0.00523	0.02582
9.5	0.00556	0.03138
10.0	0.00650	0.03788
10.5	0.00868	0.04656
11.0	0.01246	0.05902
11.5	0.01824	0.07726
12.0	0.02976	0.10702
12.5	0.05160	0.15862
13.0	0.03440	0.19302
13.5	0.02655	0.21957
14.0	0.01545	0.23502
14.5	0.01388	0.24890
15.0	0.01232	0.26122
15.5	0.01089	0.27211
16.0	0.00961	0.28173
16.5	0.00848	0.29020
17.0	0.00748	0.29768
17.5	0.00661	0.30430
18.0	0.00590	0.31019
18.5	0.00532	0.31552
19.0	0.00489	0.32040
19.5	0.00459	0.32499
20.0	0.00430	0.32930
20.5	0.00401	0.33330
21.0	0.00372	0.33702
21.5	0.00343	0.34045
22.0	0.00313	0.34358
22.5	0.00284	0.34642
23.0	0.00255	0.34897
23.5	0.00226	0.35123
24.0	0.00197	0.35319
24.5	0.00000	0.35319
25.0	0.00000	0.35319
25.5	0.00000	0.35319
26.0	0.00000	0.35319
26.5	0.00000	0.35319
27.0	0.00000	0.35319
27.5	0.00000	0.35319
28.0	0.00000	0.35319
28.5	0.00000	0.35319
29.0	0.00000	0.35319
29.5	0.00000	0.35319
30.0	0.00000	0.35319
30.5	0.00000	0.35319
31.0	0.00000	0.35319
31.5	0.00000	0.35319
32.0	0.00000	0.35319
32.5	0.00000	0.35319
33.0	0.00000	0.35319
33.5	0.00000	0.35319
34.0	0.00000	0.35319
34.5	0.00000	0.35319
35.0	0.00000	0.35319
35.5	0.00000	0.35319
36.0	0.00000	0.35319
36.5	0.00167	0.35486
37.0	0.00333	0.35819
37.5	0.00510	0.36329
38.0	0.00690	0.37019
38.5	0.00879	0.37898
39.0	0.01121	0.39019
39.5	0.01240	0.40259
40.0	0.01320	0.41579
40.5	0.01400	0.42979
41.0	0.01480	0.44459
41.5	0.01560	0.46019
42.0	0.01640	0.47659
42.5	0.01720	0.49379
43.0	0.01800	0.51179
43.5	0.01880	0.53059
44.0	0.01960	0.55019
44.5	0.02050	0.57069
45.0	0.02230	0.59299
45.5	0.02500	0.61799
46.0	0.02800	0.64599
46.5	0.03000	0.67599
47.0	0.04295	0.71894
47.5	0.05720	0.77614
48.0	0.08580	0.86194
48.5	0.04751	0.90945
49.0	0.03549	0.94494
49.5	0.03265	0.97759
50.0	0.03135	1.00894
50.5	0.02140	1.03034
51.0	0.01790	1.04824
51.5	0.01670	1.06494
52.0	0.01650	1.08144
52.5	0.01630	1.09774
53.0	0.01610	1.11384
53.5	0.01590	1.12974
54.0	0.01570	1.14544
54.5	0.01550	1.16094
55.0	0.01535	1.17629
55.5	0.01508	1.19137
56.0	0.01471	1.20608
56.5	0.01442	1.22050
57.0	0.01421	1.23471
57.5	0.01407	1.24878
58.0	0.01395	1.26273
58.5	0.01385	1.27658
59.0	0.01377	1.29035
59.5	0.01370	1.30405
60.0	0.01365	1.31770
60.5	0.01358	1.33128
61.0	0.01338	1.34466
61.5	0.01300	1.35766
62.0	0.01245	1.37011
62.5	0.01174	1.38185
63.0	0.01085	1.39270
63.5	0.00975	1.40245
64.0	0.00825	1.41070
64.5	0.00654	1.41724
65.0	0.00546	1.42270
65.5	0.00484	1.42754
66.0	0.00316	1.43070
66.5	0.00000	1.43070
67.0	0.00000	1.43070
67.5	0.00000	1.43070
68.0	0.00000	1.43070
68.5	0.00000	1.43070
69.0	0.00000	1.43070
69.5	0.00000	1.43070
70.0	0.00000	1.43070
70.5	0.00000	1.43070
71.0	0.00000	1.43070
71.5	0.00000	1.43070
72.0	0.00000	1.43070

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Chapter 5 - Runoff Treatment Facility Design

5.1 Introduction

Best Management Practices (BMPs) are schedules of activities, prohibitions of practices, maintenance procedures, managerial practices, or structural features that prevent or reduce adverse impacts to waters of Washington State. BMPs for long-term management of stormwater at developed sites can be divided into three main categories:

- BMPs addressing the volume and timing of stormwater flows;
- BMPs addressing prevention of pollution from potential sources; and
- BMPs addressing treatment of runoff to remove sediment and other pollutants.

This section of the stormwater manual focuses on the third category, treatment of runoff to remove sediment and other pollutants at developed sites. The purpose of this section is to provide guidance for selection, design, and maintenance of permanent runoff treatment facilities.

Runoff treatment facilities are designed to remove pollutants contained in stormwater runoff. The pollutants of concern include sand, silt, and other suspended solids; metals such as copper, lead, and zinc; nutrients (e.g., nitrogen and phosphorous); certain bacteria and viruses; and organics such as petroleum hydrocarbons and pesticides. Methods of pollutant removal include sedimentation/settling, filtration, plant uptake, ion exchange, adsorption, and bacterial decomposition. Floatable pollutants such as oil, debris, and scum can be removed with separator structures.

5.1.1 How to Use this Chapter

This chapter should be consulted to select specific BMPs for runoff treatment for inclusion in Stormwater Site Plans. This chapter can be used to select specific treatment facilities for permanent use at developed sites and as an aid in designing and constructing these facilities.

5.1.2 Runoff Treatment Facilities

Treatment methods and facilities described in this chapter include:

- Infiltration and Bio-infiltration (Surface Infiltration)
- Biofiltration
- Subsurface Infiltration
- Wetpool (wet pond, wet vault)
- Filtration (sand filters, media filters)
- Evaporation Pond

- Oil Control
- Phosphorous Treatment and Metals Treatment

<u>Performance Goals</u>

The water quality design storm volume and flow rates are intended to capture and effectively treat at least 90% of the annual runoff volume. Facilities that are designed, operated, and maintained according to the criteria set forth in this chapter should also capture and treat nearly all of the first flush events. Pollutant removal performance goals have been selected for each of the major categories of BMPs. These goals are:

Basic Treatment Facilities

The Basic Treatment facility choices shown in Figure 5.2.1 are intended to achieve 80% removal of total suspended solids for influent concentrations that are greater than 100 mg/l, but less than 200 mg/l. For influent concentrations greater than 200 mg/l, a higher treatment goal may be appropriate. For influent concentrations less than 100 mg/l, the facilities are intended to achieve an effluent goal of 20 mg/l total suspended solids. The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable. The goal also applies on an average annual basis to the entire annual discharge volume (treated plus bypassed).

Oil Control Facilities

The Oil Control facility choices shown in Figure 5.2.1 are intended to achieve the goals of no ongoing or recurring visible sheen, and to have a 24-hour average Total Petroleum Hydrocarbon (TPH) concentration no greater than 10 mg/l, and a maximum of 15 mg/l for a discrete sample (grab sample).

Phosphorous Treatment

The Phosphorus Treatment facility choices shown in Figure 5.2.1 are intended to achieve a goal of 50% total phosphorus removal for a range of influent concentrations of 0.1 – 0.5 mg/l total phosphorus. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained.

Metals Treatment

The Metals Treatment facility choices shown in Figure 5.2.1 are intended to provide a higher rate of removal of dissolved metals than Basic Treatment facilities. Due to the sparse data available concerning dissolved metals removal in stormwater treatment facilities, a specific numeric removal efficiency goal could not be established at the time of publication.

Instead, Ecology relied on available nationwide and local data and knowledge of the pollutant removal mechanisms of treatment facilities to develop the list of options. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal assumes that the facility is treating stormwater with dissolved copper typically ranging from 0.003 to 0.02 mg/l, and dissolved zinc ranging from 0.02 to 0.3 mg/l.

The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained. Ecology encourages the design and operation of treatment facilities that treat flows higher than the water quality design flow rate as long as the reduction in dissolved metals loading meets the performance goal.

5.2 Treatment Facility Selection Process

This section describes a process for selecting the type of treatment facilities that will apply to individual projects. Refer to Sections 5.10 and 5.11 for additional details on three of the four treatment facility options - oil control treatment, phosphorus control, and Metals Treatment.

5.2.1 Step-by-Step Selection Process for Treatment Facilities

A six-step selection process is used to aid the designer in choosing the appropriate treatment facility for a particular project. The six steps are:

Step 1: Determine Location of Site Discharge:

A. Evaporation or On-Site Dispersion
B. Combined Sanitary Sewer
C. Surface Water (directly or via conveyance system)
D. Surface Infiltration
E. Subsurface Infiltration

Step 2: If to Surface Water, Determine the Receiving Waters and Pollutants of Concern Based on Off-Site Analysis

Step 3: Determine if an Oil Control Facility/Device is Required

Step 4: Determine if Control of Phosphorous is Required

Step 5: Determine if Metals Treatment is Required

Step 6: Select a Basic Treatment Facility

The process should be used in conjunction with Figures 5.2.1 and 5.2.2.

Figure 5.2.1 BMP Selection Process

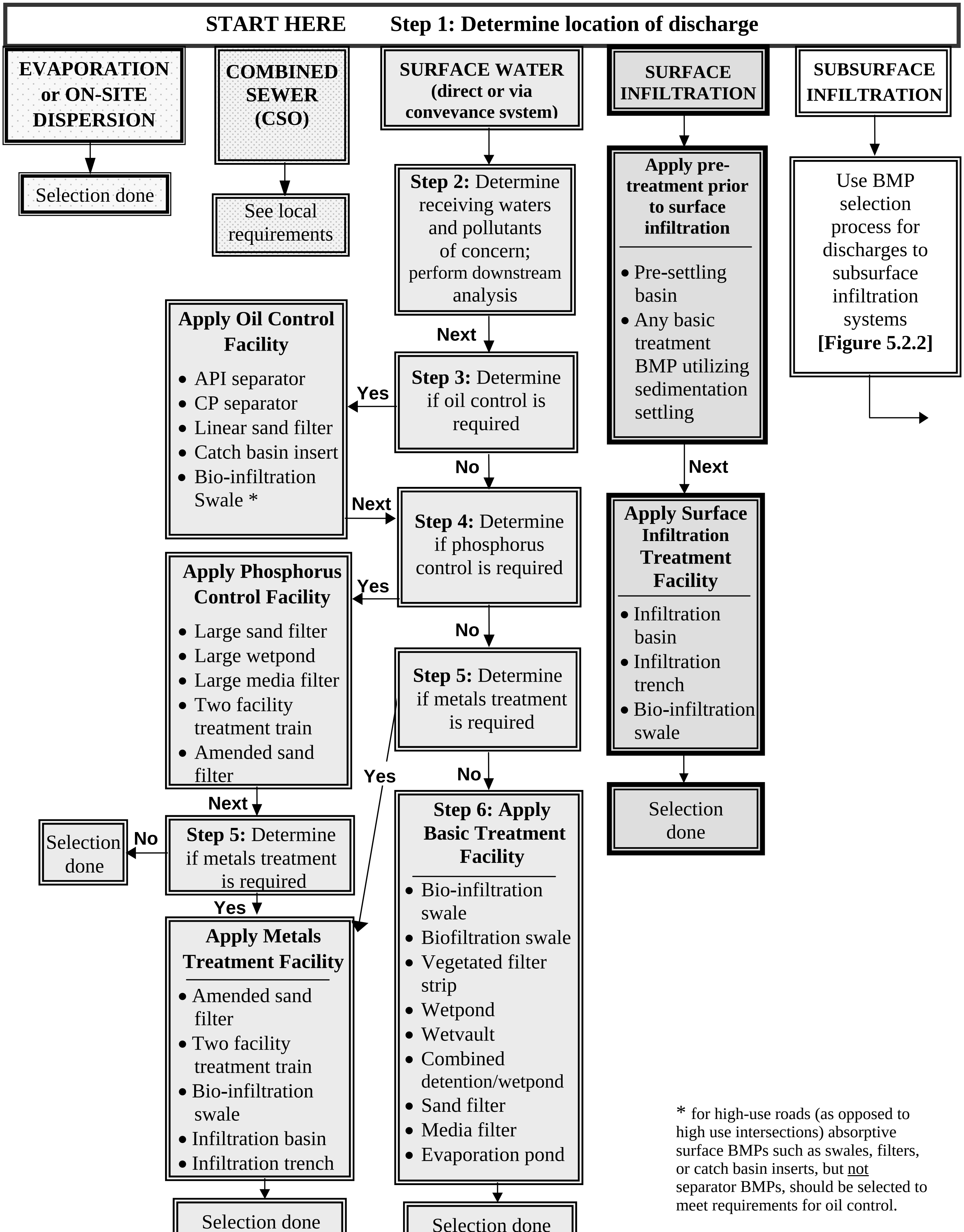


Figure 5.2.2 BMP Selection Process for Discharges to Subsurface Infiltration Systems

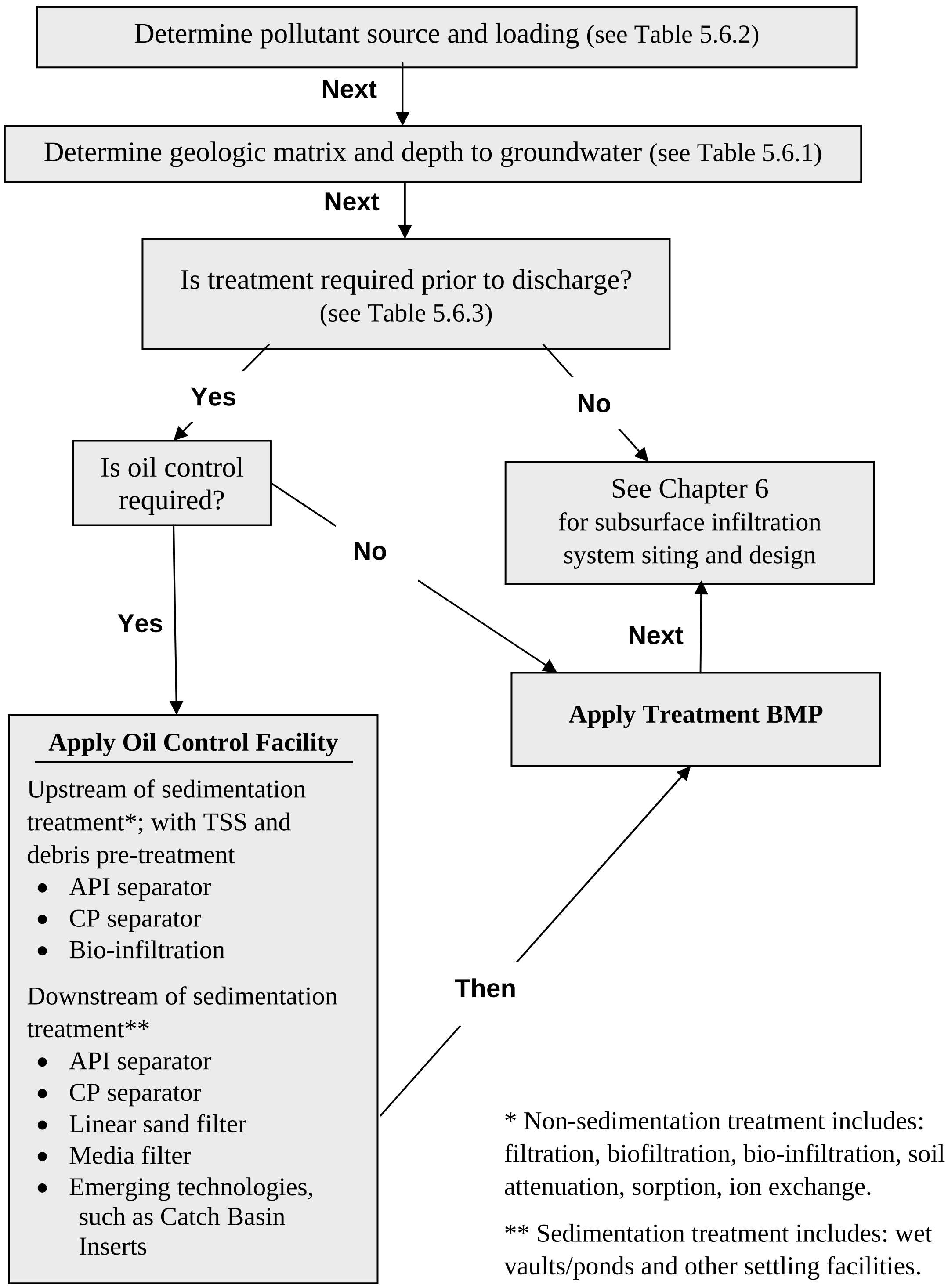


Table 5.2.1 in the following section provides information on determining pollutant sources and pollutants of concern for some land uses. Table 5.2.2 provides information on the relative ability of different treatment facilities to remove key pollutants. Table 5.2.3 provides an initial screening of treatment facilities based upon several soil types. Table 5.2.4 provides suggested stormwater treatment options for arid and semi-arid climates. Table 5.2.5 discusses cold weather challenges to BMP design. And Table 5.2.6 provides a summary of BMP applicability in cold regions.

Refer to Figure 5.2.1 for a flow chart of the steps.

Step 1: Determine Location of Site Discharge:

A. Evaporation or onsite dispersion *(no additional treatment required)*

B. Combined Sanitary Sewer *(no additional treatment required except as determined by local requirements)*

C. Surface Waters (proceed to Step 2)

D. Surface Infiltration *(proceed further with Step 1)*

E. Subsurface Infiltration *(proceed further with Step 1)*

Determine if Treatment is Required and Apply Infiltration BMP

Check the infiltration treatment design criteria in Sections 5.4.3 and 5.4.4 of this chapter. Infiltration can be effective at treating stormwater runoff, but soil properties must be appropriate to achieve effective treatment while not adversely impacting ground water resources. The location and depth to bedrock, the water table, or impermeable layers, and the proximity to wells, foundations, septic tank drainfields, and unstable slopes can preclude the use of infiltration.

Infiltration treatment facilities should be preceded by a pretreatment facility, such as a presettling basin or vault, to reduce the occurrence of plugging. Any of the basic treatment facilities, and detention ponds designed to meet flow control requirements, can also be used for pre-treatment.

If an infiltration treatment facility is planned, please refer to the Core Elements in Chapter 2. The Core Elements can affect the design and placement of facilities on your site.

Figure 5.2.2 describes a BMP selection process for discharges to subsurface infiltration facilities, including drywells. One of the initial steps is to determine pollutant source and loading. The geologic matrix and depth to ground water should be determined using the criteria and guidance in Chapter 5.6. Using Table 5.6.3, a determination is then made whether treatment is required prior to discharge. If treatment is required, appropriate controls are then selected, such as oil control, and/or other treatment BMPs as applicable. The reader should use Chapter 6 for subsurface infiltration system siting and design guidance.

The local government should verify whether any type of groundwater quality management plans and/or local ordinances or regulations have been established such as:

- **Groundwater Management Plans (Wellhead Protection Plans):** To protect groundwater quality and/or quantity, these plans may identify actions required of stormwater discharges.

Step 2: Determine the Receiving Waters and Pollutants of Concern

To obtain a more complete determination of the potential impacts of a stormwater discharge, Ecology encourages local governments to require an Off-site Analysis similar to that in Chapter 3 – Preparation of Stormwater Site Plans. Also, see Core Element #5 in Chapter 2, Section 2.2.5. Even without an off-site analysis requirement, the project proponent must determine the natural receiving water for the stormwater drainage from the project site (wetland, lake, or stream). This is necessary to determine the applicable treatment menu from which to select treatment facilities. The identification of the receiving water should be verified by the local government agency with review responsibility. If the discharge is to the local municipal storm drainage system, the receiving water for the drainage system must be determined.

The local government should verify whether any type of water quality management plans and/or local ordinances or regulations have established specific requirements for the receiving waters. The developer/owner/engineer needs to check all other agencies for requirements. Examples of plans to be aware of include:

- **Watershed or Basin Plans:** These can be developed to cover a wide variety of geographic scales (e.g., Water Resource Inventory Areas, or sub-basins of a few square miles) and can be focused solely on establishing stormwater requirements (e.g., "Stormwater Basin Plans") or can address a number of pollution and water quantity issues, including urban stormwater.
- **Water Cleanup Plans:** These plans are written to establish a Total Maximum Daily Load (TMDL) of a pollutant or pollutants in a specific receiving water or basin and to identify actions necessary to remain below that maximum loading. The plans may identify discharge limitations or management limitations (e.g., use of specific treatment facilities) for stormwater discharges from new and redevelopment projects.
- **Lake Management Plans:** These plans are developed to protect lakes from eutrophication due to inputs of phosphorus from the drainage

basin. Control of phosphorus from new development is a likely requirement in such plans.

An analysis of the proposed land use(s) of the project should also be used to determine the stormwater pollutants of concern. Table 5.2.1 lists the pollutants of concern from various land uses. Table 5.2.2 lists the ability of treatment facilities to remove key pollutants. Refer to these tables for examples of treatment options after determining whether oil control, phosphorus, enhanced, or basic treatments apply to the project. Those decisions are made in the steps below.

Step 3: Determine if an Oil Control Facility/Device is Required

The use of oil control devices and facilities is required for high-use sites. High use sites are those that typically generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil. See Core Element #5 in Chapter 2, Section 2.2.5, Guidelines section, for a description of these sites.

Application on the Project Site Oil control facilities are to be placed upstream of other facilities, as close to the source of oil generation as practical. For high-use sites located within a larger commercial center, only the impervious surface associated with the high-use portion of the site is subject to treatment requirements. If common parking for multiple businesses is provided, treatment shall be applied to the number of parking stalls required for the high-use business only. However, if the treatment collection area also receives runoff from other areas, the treatment facility must be sized to treat all water passing through it.

High-use roadway intersections shall treat lanes where vehicles accumulate during the signal cycle, including left and right turn lanes and through lanes, from the beginning of the left turn pocket. If no left turn pocket exists, the treatable area shall begin at a distance equal to three car lengths from the stop line. If runoff from the intersection drains to more than two collection areas that do not combine within the intersection, treatment may be limited to any two of the collection areas.

Oil Control Treatment Options Oil control options include facilities that are small, treat runoff from a limited area, and require frequent maintenance. The options also include facilities that treat runoff from larger areas and generally have less frequent maintenance needs. Note that for high-use roads (as opposed to high-use intersections), oil control needs to be done using absorptive surfaces such as bioswales, sand filters, or catch basin inserts, since separators would not be effective at removing the smaller quantities of oil at these sites.

- **API-Type Oil/Water Separator –** See Section 5.10
- **Coalescing Plate Oil/Water Separator –** See Section 5.10
- **Catch Basin Inserts –** See Section 5.12

- **Bio-infiltration Swales –** See Section 5.4
- **Sand Filter –** See Section 5.8

Note: *Some land use types require the use of a spill control (SC-type) oil/water separator. Those situations are described in Chapter 8 and are separate from this treatment requirement. While a number of activities may be required to use spill control (SC-type) separators, only a few will necessitate an American Petroleum Institute (API) or a coalescing plate (CP)-type separators for treatment. The following urban land uses are likely to have areas that fall within the definition of "high-use sites" or have sufficient quantities of free oil present that can be treated by an API or CP-type oil/water separator:*

- Industrial Machinery and Equipment, and Railroad Equipment Maintenance
- Log Storage and Sorting Yards
- Aircraft Maintenance Areas
- Railroad Yards
- Fueling Stations
- Vehicle Maintenance and Repair
- Construction Businesses (paving, heavy equipment storage and maintenance, storage of petroleum products).

If oil control is required for the site, please refer to the General Requirements in Sections 5.3 and 5.10.6. These requirements may affect the design and placement of facilities on the site (e.g., flow splitting). If an Oil Control Facility is required, select and apply an Oil Control Facility. Refer to the Oil Control options listed above and in Figure 5.2.1.

Step 4: Determine if Control of Phosphorous is Required

The requirement to provide phosphorous control is determined by the local jurisdiction, the Department of Ecology, or the USEPA. The local jurisdiction may have developed a management plan and implementing ordinances or regulations for control of phosphorus from new development and redevelopment for the receiving water(s) of the stormwater drainage. The local jurisdiction can use the following sources of information for pursuing plans and implementing ordinances and/or regulations:

- Those water bodies reported under section 305(b) of the Clean Water Act, and designated as not supporting beneficial uses due to phosphorous;
- Those listed in Washington State's Nonpoint Source Assessment required under section 319(a) of the Clean Water Act due to nutrients.

If phosphorus control is required, select and apply a phosphorous treatment facility. Please refer to the Phosphorus Treatment options shown in Section 5.11 and Figure 5.2.1. Select a facility after reviewing the applicability and limitations, site suitability, and design criteria of each for compatibility with the site. You may also use Tables 5.2.1 through 5.2.6 as an initial screening of options.

If you have selected a phosphorus treatment facility, please refer to the General Requirements in Section 5.3. They may affect the design and placement of the facility on the site.

Note*: Project sites subject to the Phosphorus Treatment requirement could also be subject to the Metals Treatment requirement (see Step 5). In that event, apply a facility or a treatment train that is listed in both the Metals Treatment Menu and the Phosphorus Treatment Menu.*

Step 5: Determine if Metals Treatment is Required

Metals Treatment is required for high-traffic areas and most industrial sites which discharge to fish-bearing streams, lakes, or to waters or conveyance systems tributary to fish-bearing streams or lakes. See Core Element #5 in Chapter 2, Section 2.2.5, Guidelines section, for a description of these sites.

Areas of arterials and highways, multifamily, industrial and commercial project sites that do not discharge to fish-bearing streams or lakes or are identified in a storm drainage comprehensive plan or basin plan as subject to Basic Treatment requirements are not subject to Metals Treatment requirements. For developments with a mix of land use types, the Metals Treatment requirement shall apply when the runoff from the areas subject to the Metals Treatment requirement comprise 50% or more of the total runoff to a discharge location.

If the project must apply Metals Treatment, select and apply an appropriate Metals Treatment facility. Please refer to the Metals Treatment options shown in Figure 5.2.1 and detailed in Section 5.11. Select a facility after reviewing the applicability and limitations, site suitability, and design criteria of each for compatibility with the site. You may also use Tables 5.2.1 through 5.2.6 for an initial screening of the options or parts of the two facility treatment trains.

Note*: Project sites subject to the Metals Treatment requirement could also be subject to a phosphorus removal requirement if located in an area designated for phosphorus control. In that event, apply a facility or a treatment train that is listed in both the Metals Treatment Menu and the Phosphorus Treatment Menu. If you have selected a Metals Treatment facility, please refer to the General Requirements in Section 5.3. They may affect the design and placement of the facility on the site.*

Note*: If Phosphorus Control or Metals Treatment is required, Step 6 is* not *required.*

Step 6: Select a Basic Treatment Facility

Basic Treatment options: Refer to Tables 5.2.1 through 5.2.6 as an initial screening of facilities that may be selected from to satisfy the Basic Treatment requirement.

After selecting a Basic Treatment Facility, refer to the General Requirements in Section 5.3. They may affect the design and placement of the facility on the site.

5.2.2 Other Treatment Facility Selection Factors

The selection of a treatment facility should be based on site physical factors and pollutants of concern. The types of site physical factors that influence facility selection are summarized below.

Pollutants of Concern (Table 5.2.1 and 5.2.2)

Table 5.2.1 summarizes the pollutants of concern and those land uses that are likely to generate pollutants. Table 5.2.2 suggests treatment options for each pollutant. For example, oil and grease are the expected pollutants from an uncovered fueling station. Using Table 5.2.1, a combination of an oil/water separator and a biofilter could be considered as the basic treatment for runoff from uncovered fueling stations. Table 5.2.2 is a general listing of the relative effectiveness of classes of treatment facilities in removing key stormwater pollutants.

Soil Type (Table 5.2.3)

The permeability of the soil underlying a treatment facility has a profound influence on its effectiveness. This is particularly true for infiltration treatment facilities that are best sited in sandy to loamy sand soils. They are not generally appropriate for sites that have final infiltration rates of less than 0.5 inches per hour. Wet pond facilities situated on coarser soils will need a synthetic liner or the soils amended to reduce the infiltration rate and provide treatment. Maintaining a permanent pool in the first cell is necessary to avoid re-suspension of settled solids. Biofiltration swales in coarse soils can also be amended to reduce the infiltration rate.

High Sediment Input

High TSS loads can clog infiltration soil, sand filters, and coalescing plate oil and water separators. Pretreatment with a pre-settling basin, wet vault, or another basic treatment facility would typically be necessary.

Annual Rainfall (Table 5.2.4)

Arid regions have annual rainfall less than 16 inches and semi-arid regions have annual rainfall from 16 to 35 inches. The amount of annual rainfall affects the effectiveness of BMPs that rely on vegetation for filter material or a pool of water for treatment. Table 5.2.4 identifies the preferred BMPs and the limitations to use in the arid and semi-arid climates found in most of eastern Washington.

Table 5.2.1 Typical Sources of Pollutants of Concern in Stormwater

Pollutant Sources	Pollutants of Concern
ROOFS:	
Uncoated metal	Zn
Vents & emissions(1)	O & G, TSS, Organics
PARKING LOT/DRIVEWAY:	
>High-use site	High O & G, TSS, Cu, Zn, PAH
<High-use	O & G, TSS
STREETS/HIGHWAYS:	
Arterials/highways	O & G, TSS, Cu, Zn, PAH
Residential collectors	Low O & G, TSS, Cu, Zn
High use site intersections	High O & G, TSS, Cu, Zn, PAH
OTHER SOURCES:	
Industrial/Commercial development	O & G, TSS, Cu, Zn
Residential development	TSS, Pest/ Herbicides Nutrients
Uncovered fueling stations:	High O & G
Industrial yards	High O & G, TSS, Metals, PAH

Notes:
Application of effective source control measures is the preferred approach for pollutant reduction. Where source control measures are not used, or where they are ineffective, stormwater treatment is necessary.

Legend:

Cu = Copper
O & G = Oil and Grease
PAH = Polycyclic Aromatic Hydrocarbons
PGPS = Pollution-generating pervious surface
TSS = Total Suspended Solids
Zn = Zinc

(1) Manufacturing and Food Production

Table 5.2.2[4] Ability of Treatment Facilities to Remove Key Pollutants[1] [3]

Treatment Facility	TSS	Dissolved Metals incl. Cu, Zn	Total Phosphorus	Pesticides/ Fungicides	Hydro-carbons incl. O&G, PAH
Wet Pond	■	+	+		+
Wet Vault	■				
Biofiltration	■	+	+	+	+
Sand Filter	■	+	+		+
Constructed Wetland	■	■	+	■	■
Leaf Compost Filters	■	+		■	■
Infiltration[2]	■	+		+	+
Oil/Water Separator					■
Bio-infiltration	■	■	+	■	■

Footnotes:
■ *Significant Process*
\+ *Lesser Process*
(1) *Adapted from Kulzer, King Co. Additional BMPs not included in the table, but that have metals treatment benefit, are amended sand filter, and two facility treatment trains; for phosphorus treatment are large sand filter, two facility treatment trains, and amended sand filter.*
(2) *Assumes loamy sand, sandy loam, or loam soils*
(3) *If a cell is blank, then the treatment facility is not particularly effective at treating the identified pollutant*

Table 5.2.3 Screening Treatment Facilities Based on Soil Type

Soil Type	Infiltration	Wet Pond*	Bio-Infiltration	Biofiltration* (Swale or Filter Strip)
Coarse Sand or Cobbles	-	-	-	-
Sand	■	-	-	-
Loamy Sand	■	-	■	■
Sandy Loam	■	-	■	■
Loam	-	-	■	■
Silt Loam	-	-	■	■
Sandy Clay Loam	-	■	-	■
Silty Clay Loam	-	■	-	-
Sandy Clay	-	■	-	-
Silty Clay	-	■	-	-
Clay	-	■	-	-

Notes:
■ *Indicates that use of the technology is generally appropriate for this soil type.*
\- *Indicates that use of the technology is generally not appropriate for this soil type*
* *Coarser soils may be used for these facilities if a liner is installed to prevent infiltration, or if the soils are amended to reduce the infiltration rate.*
Note: *Sand filtration is not listed because its feasibility is not dependent on soil type.*

Table 5.2.4 Suggested Stormwater Treatment Options Based on Average Annual Rainfall

Stormwater Practice	Arid Watersheds < 16 in. rainfall	Semi-Arid Watersheds 16 in. to 35 in. rainfall
Sand filters	Preferred: ▪ Requires greater pretreatment ▪ Sensitive to sediment loadings	Preferred
Bio-infiltration Swales	Acceptable with Limitations: ▪ Use dryland grass	Preferred: ▪ Use dryland or irrigated grass
Extended detention dry ponds	Preferred: ▪ Multiple storm extended detention ▪ Stable pilot channels ▪ "Dry" forebay	Acceptable: ▪ Dry or wet forebay needed
Infiltration	Acceptable with Limitations: ▪ See Table 5.6.3 ▪ Minimize erodable soils that reduce infiltration ▪ Pretreatment ▪ Soil limitations	Acceptable with Limitations: ▪ See Table 5.6.3 ▪ Minimize erodable soils that reduce infiltration ▪ Pretreatment
Wet ponds	Not Recommended: ▪ Evaporation rates are too high to maintain a normal pond without extensive use of scarce water	Limited Use: ▪ Liners to prevent water loss require water balance analysis design for a variable rather than permanent normal pool ▪ Use water sources such as AC condensate for pool ▪ Aeration unit to prevent stagnation
Stormwater wetlands	Not Recommended: ▪ Evaporation rates too great to maintain wetlands plants	Limited Use: ▪ Require supplemental water ▪ Submerged gravel wetlands can help reduce water loss
Biofiltration Swales	Not Recommended: ▪ Not recommended for pollutant removal, but rock berms and grade control needed for open channels to prevent channel erosion	Limited Use: ▪ Limited use unless irrigated or use dryland grasses ▪ Rock berms and grade control essential to prevent erosion in open channels

Adapted from: *Stormwater Strategies for Arid and Semi-Arid Watersheds*, Watershed Protection Techniques, Vol. 3, No. 3, March 2000

Other Physical Factors

- Slope: Steep site slopes restrict the use of several BMPs. A geotechnical/hydrologic evaluation should be done for sites on steeper slopes. See specific guidance for each BMP.
- High Water Table: Unless there is sufficient horizontal hydraulic receptor capacity, the water table acts as an effective barrier to exfiltration and can sharply reduce the efficiency of an infiltration system. If the high water table extends to within five (5) feet of the bottom of an infiltration BMP, the site is seldom suitable.
- Depth to Limiting Layer: The downward exfiltration of stormwater is also impeded if a bedrock or till layer lies too close to the surface. If

the impervious layer lies within five feet below the bottom of the infiltration BMP, the site is not suitable. Similarly, pond BMPs are often not feasible if bedrock lies within the area that must be excavated.

- Proximity to Foundations and Wells: The downward exfiltration of stormwater can be impeded by many different types of impervious limiting layers, including but not limited to: bedrock, hardpan, till, or clay. This can be a real problem if the BMP is located too close to a building foundation. Another risk is groundwater pollution, hence the requirement to site infiltration systems more than 100 feet away from drinking water wells.

5.2.3 Cold Weather Considerations

Objective

This section presents cold weather considerations for BMP selection and design. Discussion and guidance are given in the following areas:

- Cold weather challenges to BMP Design
- BMP applicability
- Snow and snowmelt considerations (see Section 4.2.8)

Cold Weather Challenges to BMP Design

Cold climates can present additional challenges to the selection, design, and maintenance of stormwater treatment BMPs due to one or more of the factors listed in Table 5.2.5. Engineers designing treatment BMPs in cold weather regions should be aware of these challenges and make provisions for them in their final designs.

Regions which have an average daily maximum temperature of 35 degrees or less during January, and which have a growing season less than 120 days, are especially vulnerable to the effects of cold weather. As illustrated in Figure 5.2.3, these criteria indicate that these cold weather conditions exist in many parts of eastern Washington and are therefore an important design concern.

This section of the Manual describes the general concerns common to most BMPs. Cold weather considerations specific to some individual BMPs are presented in the discussion of each methodology.

Table 5.2.5 -- Cold Weather Challenges to BMP Design

Climatic Conditions	BMP Design Challenge
Cold Temperatures	• Pipe freezing • Permanent pool ice-covered • Reduced biological activity • Reduced oxygen levels during ice cover • Reduced settling velocities • Impacts of road salt/deicers/chlorides • Winter sanding impacts on facilities
Deep Frost Line	• Frost heaving • Reduced soil infiltration • Pipe freezing
Short Growing Season	• Short time period to establish vegetation • Tolerance of plant species
Significant Snowfall	• High runoff volumes during snowmelt • High runoff during rain-on-snow • High pollutant loads during spring melt • Other impacts of road salt/deicers/chlorides • Snow management may affect BMP storage • Winter sanding impacts on facilities

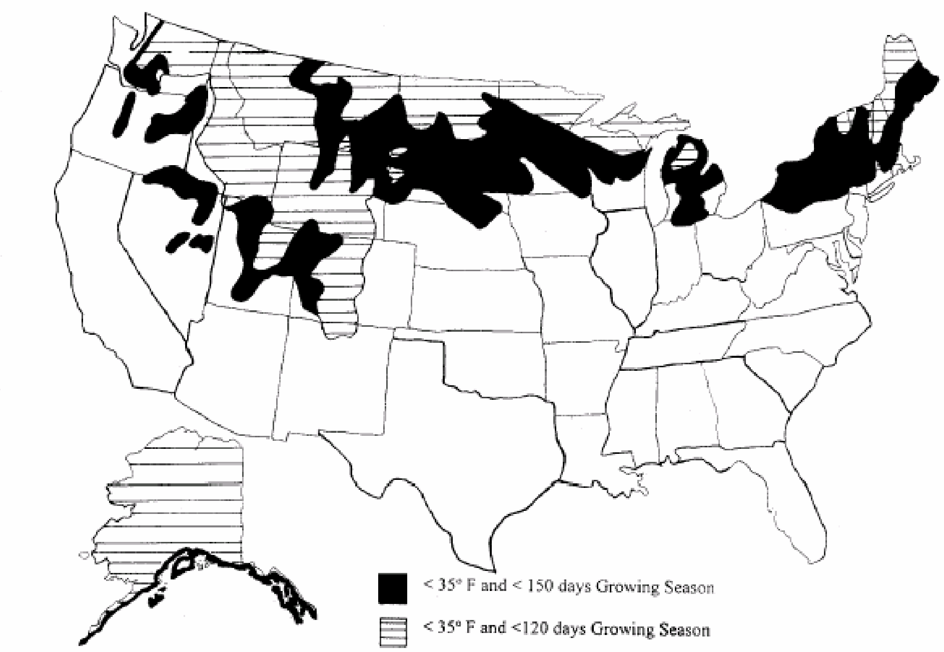
Much of the following information has been adapted from a report on Stormwater Practices for Cold Climates by the Center for Watershed Protection. The original recommendations presented in that report were based on two surveys of BMP designers from state and local governments or consulting firms. The first survey was a telephone polling of 140 individuals. The survey obtained qualitative information as well as BMP manuals. The second survey was a 6-page written questionnaire returned by 55 respondents. Additional information, including the entire manual, is available for downloading at:

http://www.stormwatercenter.net/Cold%20Climates/cold-climates.htm

The recommendations presented in the report were customized in response to regional experiences for eastern Washington. However, since local experiences are often the best measure of BMP performance, designers may want to consult with the local jurisdiction before making a final decision on the inclusion of cold weather measures. Local jurisdictions should identify BMPs that work best in their areas as well as BMPs that are not allowable due to performance considerations.

As previously noted, Table 5.2.4 contains information regarding the effects of climatic conditions on BMP design for arid and semi-arid watersheds. For cold weather considerations, several of the most common effects are briefly described in the following sections. These discussions are not meant to address every possible design detail that an engineer may face when specifying an appropriate BMP for cold weather. The goal is to identify common BMP concerns such that the designer is aware of factors that might influence their designs.

Figure 5.2.3 Overlay of Maximum January Temperature and Growing Season



Source: U.S. Department of Commerce, 1975

Many BMPs rely on some piping system for the inlet, outlet, or underdrain system. Frozen pipes can crack due to ice expansion, creating a maintenance or replacement burden. In addition, pipe freezing reduces the capability of BMPs to treat runoff for water quality and can create the potential for flooding.

Ice Formation on Wet Ponds

The permanent pool of a wet pond serves several purposes. First, the water in the permanent pool slows down incoming runoff, allowing increased settling. In addition, the biological activity in this pool can act to remove nutrients, as growing algae, plants, and bacteria require these nutrients for growth. In some systems, such as sand filters, a permanent pool acts as a pretreatment measure, settling out larger sediment particles before full treatment by the BMP.

Ice cover on the permanent pool causes two problems. First, the treatment pool's volume is reduced. Second, because the permanent pool is frozen, it acts as an impermeable surface. Runoff entering the pond will either be forced under the ice, causing scouring of the bottom sediments, or it will flow over the top of the ice, where it receives very little treatment.

Reduced Biological Activity

Many BMPs rely on biological mechanisms to help reduce pollutants, especially nutrients and organic matter. In cold temperatures, microbial activity is sharply reduced when plants are dormant during longer winters, limiting these pollutant removal pathways.

Reduced Oxygen Levels in Bottom Sediments

In cold regions, oxygen exchange between the air-water interface in ponds and lakes is restricted by ice cover. In addition, warmer water sinks to the bottom during ice cover because it is denser than the cooler water near the surface. Although biological activity is limited in cooler temperatures the decomposition that takes place does so at the bottom of wet ponds, sharply reducing oxygen concentrations in bottom sediments. In these anoxic conditions, positive ions retained in sediments can be released from bottom sediments, reducing the BMPs ability to treat these nutrients or metals in runoff.

Reduced Settling Velocities

Settling is the most important removal mechanism in many BMPs. As water becomes cooler, its viscosity increases, reducing particle settling velocity. This reduced settling velocity influences pollutant removal in any BMP that relies on settling.

Frost Heave

The primary risk of frost heave is the damage of structures such as pipes or concrete materials to construct BMPs. Another concern is that infiltration BMPs can cause frost heave damage to other structures, particularly roads. The water infiltrated into the soil matrix can flow under a permanent structure and then refreeze. The sudden expansion associated with this freezing can cause damage to above-ground structures.

Reduced Soil Infiltration

The rate of infiltration in frozen soils is limited, especially when ice lenses form. There are two results of this reduced infiltration. First, BMPs that rely on infiltration to function can be ineffective when the soil is frozen. Second, runoff rates from snowmelt are elevated when the ground underneath the snow is frozen.

Short Growing Season

For some BMPs, such as bio-infiltration swales and biofiltration swales, vegetation is integral to the proper function of the BMP. When the growing season is shortened, establishing and maintaining this vegetation becomes more difficult. Some plant species go dormant at the onset of colder temperatures, reducing the pollutant removal efficiency in BMPs that rely on actively growing plant life.

High Pollutant Loading During Winter or Spring Thaw Periods

Winter or spring melt events are important because of increased runoff volumes and pollutant loads. The snowpack contains high pollutant concentrations due to the buildup of pollutants over a several-month period. Chloride loadings are highest in snowmelt events because of the use of deicing salts, such as sodium chloride and magnesium chloride. Excessive loadings can kill vegetation in swales and other vegetative BMPs. Research indicates roughly 65% of the annual sediment, organic, nutrient, and lead loads can be attributed to winter and spring melts.

Snow Management – Plowing and Sanding

Snow management can influence water quality and impact the selection of BMPs. Dumping snow into receiving waters is discouraged. Plowing snow onto pervious surfaces can help to decrease peak runoff rates and encourage infiltration. Snow with large amounts of sand, or bare surfaces with accumulated sand, however, can result in smothering or filling the capacity of stormwater BMPs.

BMP Applicability

Based on climate conditions and design obstacles, a list of BMP applicability in cold regions is presented in Table 5.2.6. Once again, these recommendations should be used as a rule-of-thumb rather than a hard and fast rule that can be applied in all instances. Also note that in order to meet the goal of treating 90% of the annual runoff, it may be necessary to oversize facilities in cold regions.

Table 5.2.6 Summary of BMP Applicability in Cold Regions

Section ---- BMP #	BMP Category or Type	Applica-bility	Notes
5.4	***Infiltration and Bio-infiltration***		
T5.10	Infiltration Pond	fair	Can be effective but may be restricted by groundwater quality concerns related to infiltration of chlorides. Frozen ground may inhibit the infiltration capacity of ground.
T5.20	Infiltration Trench	fair	Same concerns as for Infiltration Pond
T5.21	Infiltration Swale	fair	Same concerns as for Infiltration Pond
T5.30	Bio-infiltration Swale	fair	Same concerns as for Infiltration Pond
5.5	***Biofiltration***		
T5.40	Biofiltration Swale	fair	Reduced effectiveness in the winter because of dormant vegetation. Very valuable for snow storage and meltwater infiltration.
T5.50	Vegetated Filter Strip	fair	Reduced effectiveness in the winter because of dormant vegetation. Very valuable for snow storage and meltwater infiltration.
5.6	***Subsurface Infiltration***	fair to good	Infiltration surface below frost line.
	Drywell	fair to good	Infiltration surface below frost line.
5.7	***Wetpools and Dry Ponds***		
T5.70	Basic Wetpond	fair	Can be effective but needs modifications to prevent freezing of outlet pipes. Limited by reduced treatment volume and biological activity during ice cover.
T5.71	Large Extended Detention (ED) Wetpond	good	Some modifications needed to conveyance structures. Extended detention storage provides treatment during winter season.

Table 5.2.6 Summary of BMP Applicability in Cold Regions

Section ---- BMP #	BMP Category or Type	Applica-bility	Notes
See section 5.7.3	Large Extended Detention (ED) Dry Ponds	fair	Few modifications needed to adapt to cold climates. Not highly recommended because of relatively poor warm season performance.
T5.72	Wet Vault	good	Design pool elevation below frost line or per manufacturer specs. Some modifications needed to conveyance structures.
T5.73	Extended Detention (ED) Wetland	good	Extended detention storage provides treatment during winter season. Modifications needed to wetland plant species. Some modifications needed to conveyance structures.
5.8	***Sand Filtration***		
T5.80	Basic Sand Filter	poor	Frozen ground considerations, combined with frost heave, make this ineffective in cold climates.
T5.81	Large Sand Filter	poor	Same concerns as for Basic Sand Filter.
T5.82	Sand Filter Vault	good	Design filter elevation below frost line or per manufacturer specs
T5.83	Linear Sand Filter	poor to fair	Design filter elevation below frost line or per manufacturer specs. Cold conditions may plug surface inlet and impact performance.
5.9	***Evaporation Ponds***	fair to good	Evaporation not expected to result in significant water losses during cold weather; hence must size to provide adequate storage.
5.10	***Oil and Water Separator***		
T5.100	API Separator Bay	poor to fair	Check with the manufacturer for cold weather applicability.
T5.110	Coalescing Plate Bay	poor to fair	Check with the manufacturer for cold weather applicability.

5.3 General Requirements for Stormwater Facilities

This section addresses general requirements for treatment facilities. Requirements discussed in this section include design volumes and flows, sequencing of facilities, and basic siting requirements for treatment facilities.

5.3.1 Design Volume and Flow

Water Quality Design Storm Volume

Refer to Chapter 4 and Chapter 2.2.5 for information on design storms and the determination of peak flow rates and storm volumes.

“On-line” Systems

Most treatment facilities can be designed as “on-line” systems with flows above the water quality design flow or volume simply passing through the facility with lesser or no pollutant removal. However, it is sometimes desirable to restrict flows to treatment facilities and bypass the remaining higher flows around them. These are called “off-line” systems. An example of an on-line system is a biofiltration swale with overflow to a drywell.

Bypass Requirements

A bypass or overflow structure must be provided for all treatment BMPs unless the facility is able to convey the 25-year short duration storm without damaging the BMP or dislodging pollutants from within it. Bypass or overflow provisions must be provided for all flow-rate-based treatment BMPs and for volume-based treatment BMPs that require them. See local requirements for typical designs.

To design a bypass for a flow-rate-based runoff treatment facility:

1. Determine the maximum allowable velocity that will not result in damage of the facility or dislodging of pollutants from within it.

2. Size an orifice or weir in a flow splitter manhole, vault, etc., such that the maximum velocity is not exceeded for the 25-year event.

3. Size overflow (bypass) conveyance system to handle bypass flows.

To design a bypass for a volume-based runoff treatment facility such as a bioinfiltration swale, maintain an elevated inlet or other overflow structure that bypasses flows above the design volume for the treatment facility instead of using a flow-rate-based device. The bypassed water may flow to another treatment facility or directly into a conveyance system or infiltration facility. Bypass is not recommended for wet ponds, constructed wetlands, and similar volume-based treatment facilities. Inlet structures for these facilities should be designed to dampen velocities; the pond dimensions will further dissipate the energy. In these facilities, larger storms will be retained for a shorter detention time than the shorter storms for which the ponds are designed.

Summary of Areas Needing Treatment

All runoff from pollution-generating impervious surfaces meeting permitted thresholds is to be treated through the water quality facilities as required by Core Element #5.

- Lawns and landscaped areas specified are pervious but may also generate run-off into street drainage systems. In those cases the runoff from the pervious areas must be estimated and added to the runoff from impervious areas to size treatment facilities.
- Drainage from impervious surfaces that are not pollution-generating need not be treated and may bypass runoff treatment, if it is not mingled with runoff from pollution-generating surfaces.
- Runoff from metal roofs must be treated unless the roofs are coated with an inert non-leachable material.
- Drainage from areas in native vegetation should not be mixed with untreated runoff from streets and driveways, if possible. It is best to infiltrate or disperse this relatively clean runoff to maximize recharge to shallow ground water, wetlands, and streams.
- If runoff from non-pollution generating surfaces reaches a runoff treatment BMP, flows from those areas must be included in the sizing calculations for the facility. Once runoff from non-pollution generating areas is mixed with runoff from pollution-generating areas, it cannot be separated before treatment.

5.3.2 Sequence of Facilities

In general, all treatment facilities may be installed upstream of detention facilities. However, not all treatment facilities can function effectively if located downstream of detention facilities. Those facilities that treat unconcentrated flows, such as filter strips, are usually not practical downstream of detention facilities. Other types of treatment facilities present special problems that must be considered before placement downstream of detention. These would include biofiltration swales or sand filters which are sensitive to saturation and continuous flow.

Oil control facilities may be located upstream or downstream of treatment facilities and as close to the source of oil-generating activity as possible. They should also be located upstream of detention facilities, if possible.

5.3.3 Setbacks, Slopes, and Embankments

The following guidelines for setbacks, slopes, and embankments are intended to provide for adequate maintenance accessibility to runoff treatment facilities. Setback requirements are generally required by local regulations, Uniform Building Code requirements, or other state regulations. Local governments should require specific setback, slopes and embankment limitations to address public health and safety concerns.

Setbacks

Local governments may require specific setbacks in sites with steep slopes, land-slide areas, open water features, springs, wells, and septic tank drain fields. Setbacks from tract lines are necessary for maintenance access and equipment maneuverability. Adequate room for maintenance equipment should be considered during site design.

<u>*Examples* of setbacks commonly used include the following</u>:

- Stormwater infiltration systems shall be set back at least 100 feet from open water features and 200 feet from springs used for drinking water supply. Infiltration facilities upgradient of drinking water supplies must comply with Health Department requirements (Washington Wellhead Protection Program, Department of Health, 12/93).
- Stormwater infiltration systems and unlined wetponds and detention ponds shall be located at least 100 feet from drinking water wells and septic tanks and drainfields.
- All facilities should be located away from any steep slope (greater than 15%), at a minimum distance equivalent to the height of the slope. A geotechnical report must address the potential impact of any facilities sited on or near a steep slope.

Side Slopes and Embankments

- Side slopes should preferably not exceed a slope of 3H:1V. Moderately undulating slopes are acceptable and can provide a more natural setting for the facility. In general, gentle side slopes improve the aesthetic attributes of the facility and enhance safety.
- Interior side slopes may be retaining walls. The design shall be prepared and stamped by a licensed civil engineer, when required by code. A fence should be provided along the top of the wall.
- Maintenance access should be provided through an access ramp or other adequate means.
- Embankments that impound water must comply with the Washington State Dam Safety Regulations (Chapter 173-175 WAC). If the impoundment has a storage capacity, including both water and sediment storage volumes, greater than 10 acre-feet above natural

ground level, then dam safety design and review are required by the Department of Ecology. See Chapter 6 for more detail concerning Detention Ponds.

5.3.4 Maintenance Standards for Drainage Facilities

Each of the BMP sections which follows includes specific maintenance criteria the designer needs to be aware of when selecting that BMP. More information on maintenance criteria for all BMPs is included in Appendix 5A of this chapter.

5.4 Surface Infiltration and Bio-infiltration Treatment Facilities

5.4.1 Purpose

A stormwater infiltration treatment facility is an impoundment, typically a pond, trench, or bio-infiltration swale whose underlying soil removes pollutants from stormwater. These facilities serve the dual purpose of removing pollutants (TSS, heavy metals, phosphates, and organics) from stormwater and recharging aquifers. Infiltration treatment soils must contain sufficient organic matter and/or clays to sorb, decompose, and/or filter stormwater pollutants. Pollutant/soil contact time, soil sorptive capacity, and soil aerobic conditions are important design considerations.

The infiltration BMPs described in this section include:

- BMP T5.10 Infiltration ponds
- BMP T5.20 Infiltration trenches
- BMP T5.21 Infiltration swales
- BMP T5.30 Bio-infiltration swales (grassed percolation area)

5.4.2 Application

These infiltration and bio-infiltration treatment measures are capable of achieving the performance objectives cited in Section 5.1 for specific treatment menus. In general, these treatment techniques can capture and remove or reduce the target pollutants to levels that:

- Will not adversely affect public health or beneficial uses of surface and groundwater resources, and
- Will not cause a violation of groundwater quality standards

An infiltration trench or bio-infiltration swale is preferred, but an infiltration basin may be more applicable where an infiltration trench or bio-infiltration swale cannot be sufficiently maintained.

5.4.3 General Considerations for Infiltration and Bio-infiltration Facilities

Discussed below are several considerations common to infiltration and bio-infiltration treatment.

Design Infiltration Rate Determination

See Chapter 6 – Flow Control Facility Design, for information on determining infiltration rates. The following table (Table 5.4.1) can be used for determining presumptive rates for surface treatment facilities based on the USDA soil classification or the Unified Soil Classification System. See Appendix 6B for additional guidance in determining infiltration rates.

Table 5.4.1 Infiltration rates for surface infiltration and bio-infiltration facilities

USDA Soil Textural Classification	Unified Soil Classification System Group Symbol [1]	Presumptive Infiltration Rate (inches/hour) [4]
Sand	SP-SM	See Note 2
Sand	SP-SC	See Note 2
Loamy Sand	SM, SC	2 [3]
Sandy Loam	SM, SC	1 [3]
Loam	ML, MH	0.5 [3]

Notes:

1. Groups contain from two to eight soil types distinguished by Group Name.
2. Not suitable for infiltration treatment unless justified by geotechnical study and approved by permitting municipality.
3. These are short-term infiltration rates from Washington State Department of Ecology, *Stormwater Management Manual for Western Washington*, August 2001, Publication Numbers 99-11 through 99-15. Site conditions, including depth to the water table, will affect the application of these rates in eastern Washington. Long-term rates are used for designing BMPs: a very general rule for determining the long-term infiltration rate is to divide the short-term rate by a factor of two to four, depending on the soil classification and site conditions. A correction factor higher than four should be considered for situations where long-term maintenance will be difficult to implement, where little or no pretreatment is anticipated, or where site conditions are highly variable or uncertain. These situations require the use of best professional judgment by the site engineer and may also require the approval of the local jurisdiction.
4. See Appendix 6B for alternative approaches to determining infiltration rates.

Site Suitability Criteria (SSC)

This section specifies the site suitability criteria that must be considered for siting infiltration treatment systems. Check with the local jurisdiction for reporting requirements and other possible requirements specific to local conditions. When a site investigation reveals that any of the seven applicable criteria cannot be met, appropriate mitigation measures must be implemented so that the infiltration facility will not pose a threat to human safety and health and the environment.

For infiltration treatment, site selection, and design decisions, a geotechnical and hydrogeologic report should be prepared by a registered professional engineer with geotechnical expertise, or a registered geologist with hydrogeology specialty, if required by the site suitability criteria or local jurisdiction requirements.

The seven site suitability criteria are as follows:

SSC-1 Setback Criteria

Setback requirements are generally required by local regulations, Uniform Building Code requirements, or state regulations. These Setback Criteria are provided as guidance.

Facilities must be greater than 100 feet from: drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies. Infiltration facilities upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones must comply with Health Department requirements (Washington Wellhead Protection Program, DOH, 12/93).

Note: *Additional setbacks should be considered if roadway deicers or herbicides are likely to be present in the influent to the infiltration system.*

- From building foundations: ≥ 20 feet downslope and 100 feet upslope
- From a Native Growth Protection Easement (NGPE): ≥ 20 feet
- From the top of slopes >15%: Setback distance 50 feet minimum or as determined by a professional engineer. Also check local Critical Area Ordinances.

Also evaluate on-site and off-site structural stability due to extended subgrade saturation and/or head loading of the permeable layer, including the potential impacts to downgradient properties, especially on hills with known side-hill seeps.

SSC-2 Groundwater Protection Areas

A site is not suitable if the infiltrated stormwater will cause a violation of Ecology's Groundwater Quality Standards. Local jurisdictions should be consulted for applicable pretreatment requirements and whether the site is located in an aquifer sensitive area, sole source aquifer, or a wellhead protection zone. See SSC-7 for verification testing guidance.

SSC-3 Soil Infiltration Rate/Drawdown Time

The long-term soil infiltration rate should be a minimum of 0.5 inches per hour and a maximum of 2.4 inches per hour to a depth of 2.5 times the maximum design flooded depth. This infiltration rate is typical for soil textures that possess sufficient physical and chemical properties for adequate treatment, particularly for soluble pollutant removal (see SSC-5).

It is comparable to the textures represented by Hydrologic Groups B and C. Check for local requirements for infiltration rates.

It is necessary to empty the maximum ponded depth (water quality volume) from the infiltration basin within 72 hours from the completion of inflow to the storage pond in order to meet the following objectives:

- Restore hydraulic capacity to receive runoff from a new storm.
- Maintain infiltration rates.
- Aerate vegetation and soil to keep the vegetation healthy, prevent anoxic conditions in the treatment soils, and enhance the biodegradation of pollutants and organics.

SSC-4 Depth to Bedrock, Water Table, or Impermeable Layer

The base of all infiltration basins or trench systems should be ≥ 5 feet above the seasonal high-water mark, bedrock (or hardpan) or other low permeability layer. A minimum separation of 3 feet may be considered if the groundwater mounding analysis, volumetric receptor capacity, and the design of the overflow and/or bypass structures are judged by the professional engineer to be adequate to prevent overtopping and to meet the site suitability criteria specified in this section.

SSC-5 Soil Physical and Chemical Suitability for Treatment

The soil texture and design infiltration rates should be considered along with the physical and chemical characteristics specified below to determine if the soil is adequate for removing the target pollutants. The following soil properties should be carefully considered in making such a determination:

- Cation exchange capacity (CEC) of the treatment soil must be ≥ 5 milliequivalents CEC/100 g dry soil (USEPA Method 9081). Consider empirical testing of soil sorption capacity, if practicable. Ensure that soil CEC is sufficient for expected pollutant loadings, particularly heavy metals. CEC values of >5 meq/100g are expected in loamy sands, according to Rawls, et al. Lower CEC content may be considered if it is based on a soil loading capacity determination for the target pollutants that is accepted by the local jurisdiction.
- Depth of soil used for infiltration treatment must be a minimum of 18 inches except for designed, vegetated infiltration facilities with an active root zone such as bio-infiltration swales.
- Organic content of the treatment soil (ASTM D 2974): Organic matter can increase the sorptive capacity of the soil for some pollutants. The site professional should evaluate whether the organic matter content is sufficient for control of the target pollutant(s).

- Waste fill materials should not be used as infiltration soil media nor should such media be placed over uncontrolled or non-engineered fill soils.
- Engineered soils may be used to meet the design criteria in this section. Field performance evaluation(s), using acceptable protocols, would be needed to determine feasibility and acceptability by the local jurisdiction.
- Local jurisdictions may establish pre-approved soil types for treatment suitability. Check locally for specific allowances and requirements.

SSC-6 Seepage Analysis and Control

Determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots, or sloping sites. Infiltration of stormwater is not recommended on or up-gradient of contaminated sites where infiltration of even clean water can cause contaminants to mobilize. Refer to SSC for Chapter 6 on filtration.

SSC-7 Construction Monitoring

The professional engineer should monitor the construction of the infiltration facility to ensure that the work is completed in compliance with the designer's intent and the plans and specifications. Following construction, the facility should be visually monitored quarterly over a two-year period to assess its performance as designed.

General Information for Infiltration Basins, Trenches, and Bio-infiltration Swales

This section covers the general design, construction, and maintenance criteria that apply to infiltration basins, trenches, and bio-infiltration swales.

Sizing Criteria: Size should be determined by using the method(s) outlined with each BMP, based on the requirement of infiltrating the Water Quality Design Storm Volume within 72 hours after cessation of flow.

Construction Criteria

- Excavation - Initial excavation should be conducted to within 1-foot of the final elevation of the floor of the infiltration facility. Final excavation to the finished grade should be deferred until all disturbed areas in the upgradient watershed have been stabilized or protected. The final phase of excavation should remove all accumulated sediment. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a pre-settling basin, wet pond, or sand filter.

- Infiltration facilities should generally not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized. Any accumulation of silt in the basin must be removed before putting it in service.
- Traffic Control - Relatively light-tracked equipment is recommended for excavation to avoid compaction of the floor of the infiltration facility. The use of draglines and trackhoes should be considered. The infiltration area should be flagged or marked to keep equipment away.

Maintenance Criteria

- Provision should be made for regular and perpetual maintenance of the infiltration basin/trench, including replacement and/or reconstruction of the treatment infiltration medium. Maintenance should be conducted when water remains in the basin or trench for more than 72 hours or overflows the basin/pond. Adequate access for O&M must be included in the design of infiltration basins and trenches. An Operation and Maintenance Plan, approved by the local jurisdiction, should ensure maintaining the desired efficiency of the infiltration facility.
- Debris/sediment accumulation - Removal of accumulated debris/sediment in the basin/trench should be conducted every six months or as needed to prevent clogging, or when water remains in the pond for greater than 72 hours.
- The treatment soil should be replaced or amended as needed to ensure it is maintaining adequate treatment capacity.

Verification of Performance

- During the first 1-2 years of operation, verification monitoring as specified in SSC-7 is strongly recommended. Operating and maintaining groundwater monitoring wells is also strongly encouraged.

5.4.4 Best Management Practices (BMPs) for Infiltration and Bio-infiltration Treatment

The three BMPs discussed below are recognized currently as effective treatment techniques using infiltration and bio-infiltration. Selection of a specific BMP will depend upon having followed the Treatment Facility Selection Process in Section 5.2.

BMP T5.10 Infiltration Ponds

Description Infiltration ponds are earthen impoundments used for the collection, temporary storage, and infiltration of incoming stormwater runoff.

UIC regulations do not apply to these facilities unless the pond is deeper than it is wide at the ground surface, and then – provided that the design, operation, and maintenance criteria in this section are met – only the registration requirement would apply. See section 5.6.

Design Criteria Design of infiltration ponds for water quality treatment is identical to the criteria given in Section 6.3.5 for BMP F6.21 Infiltration Ponds, except that the allowable infiltration rate is limited to 2.4 in/hr or less.

BMP T5.20 Infiltration Trenches

Description Infiltration trenches are trenches, generally at least 24 inches wide, with a perforated pipe and backfilled with a coarse stone aggregate, allowing for temporary storage of stormwater runoff in the voids of the aggregate material. Stored runoff then is gradually infiltrated into the surrounding soil.

UIC regulations apply to these facilities when perforated pipe is used, and then – provided that the design, operation, and maintenance criteria in this section are met – only the registration requirement applies. When perforated pipe is not used, the registration requirement does not apply. See section 5.6

Design Criteria The design of infiltration trenches for water quality treatment is identical to the criteria given in Section 6.3.5 for BMP F6.22 Infiltration Trenches, except that the allowable infiltration rate is limited to 2.4 in/hr or less.

BMP T5.21 Infiltration Swales

Description Infiltration swales are conveyances designed for removal of stormwater pollutants by percolation into the ground.

UIC regulations do not apply to these facilities (see section 5.6).

Design Criteria The design of infiltration swales for water quality treatment is identical to bio-infiltration swales (BMP T5.30, below) except that amended soil may be required to meet SSC-5 (Soil Physical and Chemical Suitability for Treatment). Greater soil depth is required for treatment because there is no uptake by vegetation. Appropriate vegetation or a landscaped rock surface such as river rock or crushed basalt is recommended for aesthetic purposes and for dust and erosion control.

BMP T5.30 Bio-infiltration Swale

Description Bio-infiltration swales, also known as grassed percolation areas, combine grasses (or other vegetation) and soils to remove stormwater pollutants by percolation into the ground. Their pollutant removal mechanisms include filtration, soil sorption, and uptake by vegetated root zones. Bio-infiltration swales have been used in Spokane County for many years to treat urban stormwater and recharge the ground water.

In general, bio-infiltration swales are used for treating stormwater runoff from roofs, roads, and parking lots. For flow control, flows greater than the Water Quality Design flows are typically overflowed to the subsurface through an appropriate conveyance facility such as a dry well, or to surface water through an overflow channel. Note that although UIC regulations do not apply to the swales in these facilities, the regulations do apply to any drywell used in connection with the swale (see section 5.6).

Design Criteria

Bio-infiltration swales may be sized using several different design methods. Each of the approaches is valid in the context of this manual, although the local jurisdiction may, at its option, direct the designer to use a particular method.

Basic Design Method: This method prescribes a set runoff volume to be used in calculating the treatment volume of the bio-infiltration swale, based on the 2-year 24-hour precipitation at the site and the design infiltration rate. Table 5.4.2 and 5.4.3 illustrate the amount of runoff from 1,000 square feet of impervious area for various regions of eastern Washington. The appropriate value for the site may be used to calculate the required volume of the bio-infiltration facility.

$V = A_i R / 1{,}000$

Where: V = volume of the bio-infiltration swale (cu. ft.)
A_i = impervious area draining to bio-infiltration swale (sq. ft.)
R = runoff volume ratio shown in the third column of Tables 5.4.2 and 5.4.3

Alternative Design Method: This method uses the first one-half inch of runoff from impervious surfaces to size the bio-infiltration swale. This method is applicable only in Climate Regions 2 and 3.

$V = (A_i)(0.5 \text{ in.})/(12 \text{ in./ft.})$

Where: V = volume of the bio-infiltration swale (cu. ft.)
A_i = impervious area needing treatment that drains to the bio-infiltration swale (sq. ft.)

This method matches Spokane County's methodology by using the first one-half inch of runoff from pollutant-generating impervious surfaces that are hydraulically connected to the treatment facility to size the bio-infiltration swale. This method does not require treatment of permeable surfaces and does not give credit for infiltration through the bottom of the swale. The treatment depth is typically six inches. A maximum treatment depth of eight inches is allowed if cation exchange capacity testing indicates that CEC is 15 meq/100g or greater. CEC testing can be completed post-construction or a soil amendment that meets the CEC requirements can be specified on the construction drawings. The swale is sized to store the required runoff volume (using the design storm established by the local jurisdiction; the 25-year SCS Type IA storm is the default design storm) generated by the contributing basin. The swale is sized using the entire swale depth, typically no deeper than one foot, in conjunction with a subsurface infiltration facility such as a drywell.

Table 5.4.2 Bio-infiltration swale sizing table for design infiltration rates in the range of 0.15 to 0.40 inches/hour

2-YEAR 24-HOUR PRECIPITATION (in)		SWALE VOLUME PER 1000 SQUARE-FEET OF IMPERVIOUS AREA	EXAMPLES OF APPLICABLE SITES
FROM	TO		
0.60	0.80	29.2 cubic-feet	Moses Lake
0.81	1.00	37.5 cubic-feet	Yakima, Kennewick
1.01	1.20	45.8 cubic-feet	Wenatchee, Walla Walla
1.21	1.40	55.8 cubic-feet	Colfax, Colville
1.41	1.55	61.3 cubic-feet	Lowlands Blue Mountains
1.56	and greater	Hydrograph Method Required	Eastern and Cascade Mountains

Table 5.4.3 Bio-infiltration swale sizing table for design infiltration rates in the range of 0.41 to 1.00 inches/hour

2-YEAR 24-HOUR PRECIPITATION (in)		SWALE VOLUME PER 1000 SQUARE-FEET OF IMPERVIOUS AREA	EXAMPLES OF APPLICABLE SITES
FROM	TO		
0.60	0.80	19.6 cubic-feet	Moses Lake
0.81	1.00	25.4 cubic-feet	Yakima, Kennewick
1.01	1.20	27.9 cubic-feet	Wenatchee, Walla Walla
1.21	1.40	33.8 cubic-feet	Colfax, Colville
1.41	1.55	36.7 cubic-feet	Lowlands Blue Mountains
1.56	and greater	Hydrograph Method Required	Eastern and Cascade Mountains

Hydrograph Design Methods

These methods use hydrologic models, such as SCS or the Santa Barbara Urban Hydrograph, to determine the quantity of runoff from the Water Quality Design Storm and then route the flow through the infiltration facility, assuming the long-term infiltration rate is used for the outflow calculations. This method is required in areas with greater than 1.56 inches of rainfall in the 2-year 24-hour storm and allowed in all other areas with the approval of the local jurisdiction. See Chapter 4 for more information on hydrologic methods.

Additional Design Criteria for Bio-infiltration Swales

- Use the same sizing guidance, off-line and on-line guidance, and design procedures as in Section 6.3.4.
- The maximum drawdown time for the flooded depth should be within 72 hours after cessation of flow.
- A concrete or riprap apron shall be provided at the curb opening to prevent vegetation from blocking the inlet.
- The swale bottom should be flat with a longitudinal slope less than 1%.
- The maximum flood depth of swale should be 6 inches, prior to overflow to a drywell or other infiltrative or overflow facility.
- The volume contained by the swale must be sufficient for the water quality volume to be treated prior to overflow or infiltration.
- The treatment soil should be at least 6 inches thick with a CEC of at least 5 meq/100 gm dry soil, organic content of at least 1%, and sufficient target pollutant loading capacity. (See Criteria for Assessing the Trace Element Removal Capacity of Bio-filtration Systems, Stan Miller, Spokane County, June 2000).
- Other combinations of treatment soil thickness, CEC, and organic content design factors can be considered if it is demonstrated that the soil and vegetation will provide a target pollutant loading capacity and performance level acceptable to the local jurisdiction.
- The treatment zone depth of 6 inches or more should contain sufficient organics and texture to ensure good growth of the vegetation.
- The average infiltration rate of the 6-inch thick layer of treatment soil should not exceed 1-inch per hour for a system relying on the root zone to enhance pollutant removal. Furthermore, a maximum infiltration rate of 2.4 inches per hour is applicable and Site Suitability Criteria in Section 5.4.3 must also be applied.
- Native grasses, adapted grasses, or other vegetation with significant root mass should be used. Grasses should be drought tolerant or irrigation should be provided.
- Pretreatment may be used to prevent the clogging of the treatment soil and/or vegetation by debris, TSS, and oil and grease.

Identify pollutants, particularly in industrial and commercial area runoff, that could cause a violation of Ecology's groundwater quality standards

(Chapter 173-200 WAC). Include appropriate mitigation measures (pretreatment, source control, etc.) for those pollutants.

5.5 Biofiltration Treatment Facilities

5.5.1 Purpose

Biofiltration treatment facilities are vegetated treatment systems (typically grass) that remove pollutants by means of sedimentation, filtration, soil sorption, and/or plant uptake. They are typically configured as swales or filter strips. These facilities are designed to remove low concentrations and quantities of total suspended solids (TSS), heavy metals, petroleum hydrocarbons, and/or nutrients from stormwater. The biofiltration BMPs described in this section include:

- BMP T5.40 Biofiltration swales
- BMP T5.50 Vegetated filter strip

5.5.2 Application

Biofiltration treatment facilities can be used as a basic treatment BMP for contaminated runoff from roadways, driveway, parking lots, and highly impervious ultra-urban areas or as the first stage of a treatment train. In cases where hydrocarbons, high TSS, or debris would be present in the runoff, such as high-use sites, a pretreatment system for those components would be necessary. Off-line location is preferred to avoid flattening vegetation and the erosive effects of high flows.

5.5.3 Best Management Practices (BMPs) for Biofiltration Treatment

The two BMPs discussed below are recognized currently as effective treatment techniques using biofiltration. Selection of a specific BMP should be coordinated with the Treatment Facility options provided in Section 5.2.

BMP T5.40 - Biofiltration Swale

Biofiltration is the simultaneous process of filtration, particle settling, adsorption, and biological uptake of pollutants in stormwater that occurs when runoff flows over and through vegetated areas. A biofiltration swale is a sloped, vegetated channel or ditch that provides both conveyance and water quality treatment to stormwater runoff. It does not provide stormwater quantity control but can convey runoff to BMPs designed for that purpose.

UIC regulations do not apply to these facilities (see section 5.6).

General Criteria

- Though the actual dimensions for a specific site may vary, the swale should generally have a length of 200 feet. The maximum bottom width is typically 10 feet. The depth of flow should not exceed 4 inches during the design storm. The flow velocity should not exceed 1 ft/sec.
- The channel slope should be at least 1 percent and no greater than 5 percent.
- The swale can be sized as both a treatment facility for the 6-month storm and as a conveyance system to pass the peak hydraulic flows of the 25-year storm if it is located "on-line."
- The ideal cross section of the swale should be a trapezoid. The side slopes should be no steeper than 3:1.
- Roadside ditches should be regarded as significant potential biofiltration sites and should be utilized for this purpose whenever possible.
- If flow is to be introduced through curb cuts, place pavement slightly above the biofilter elevation. Curb cuts should be at least 12 inches wide to prevent clogging.
- Biofilters must be vegetated in order to provide adequate treatment of runoff.
- It is important to maximize water contact with vegetation and the soil surface. For general purposes, select fine, close-growing grasses (or other vegetation) that can withstand prolonged periods of wetting, as well as prolonged dry periods (to minimize the need for irrigation). Consult the local NRCS office or the County Extension Service for specific vegetation selection recommendations.
- Biofilters should generally not receive construction-stage runoff. If they do, pre-settling of sediments should be provided. See BMPs C240 (Sediment Trap) and C241 (Temporary Sediment Pond) in Chapter 7 – Construction Stormwater Pollution Prevention. Such biofilters should be evaluated for the need to remove sediments and restore vegetation following construction. The maintenance of pre-settling basins or sumps is critical to their effectiveness as pretreatment devices.
- If possible, divert runoff (other than necessary irrigation) during the period of vegetation establishment. Where runoff diversion is not possible, protect graded and seeded areas with suitable erosion control measures.

Design Procedure

- **Step 1** - Determine the peak flow rate to the biofilter from the Water Quality Design Storm. See Chapter 4.
- **Step 2** - Determine the slope of the biofilter. This will be somewhat dependent on where the biofilter is placed. The slope should be at least 1 percent and shall be no steeper than 5 percent. When slopes less than 2 percent are used, the need for underdrainage must be evaluated.
- **Step 3** - Select a swale shape. Trapezoidal is the most desirable shape; however, rectangular and triangular shapes can be used. The remainder of the design process assumes that a trapezoidal shape has been selected.
- **Step 4** - Use Manning's Equation to estimate the bottom width of the biofilter. Manning's Equation for English units is as follows:

$$Q = (1.486\ A\ R^{0.667}\ S^{0.5})\ /\ n$$

Where: Q = flow (cfs)

A = cross sectional area of flow (ft^2)

R = hydraulic radius of flow cross section (ft)

S = longitudinal slope of biofilter (ft/ft)

n = Manning's roughness coefficient. Values for grasses range from 0.15 to 0.40. Use n = 0.30 for a typical biofilter with turf/lawn vegetation; n = 0.20 for a biofilter with less dense vegetation such as meadow or pasture; or other n values for specific site vegetation as determined by the site professional. These values may be subject to approval by the project review authority.

For a trapezoid, this equation cannot be directly solved for bottom width. However, for trapezoidal channels that are flowing very shallow, the hydraulic radius can be set equal to the depth of flow. Using this assumption, the equation can be altered to:

$$B = ((0.135\ Q)\ /\ (y^{1.667}\ S^{0.5}))\text{-}zy$$

For n = 0.20 and where:

B = bottom width of the swale

y = depth of flow

Z = the side slope of the biofilter in the form of z:1

For other values of n, use the following equation:

$$B = (((n\ /\ 1.486)\ Q)\ /\ (y^{1.667}\ S^{0.5}))\text{-}zy$$

Typically, the depth of flow for turf grass is selected to be 4 inches. For dryland grasses the depth of flow should be set to 3 inches. It can be set lower but doing so will increase the bottom width. Sometimes when the flow rate is very low the equation listed above will generate a negative value for B. Since it is not possible to have a negative bottom width, the bottom width should be set to 1 foot when this occurs.

Biofilters are limited to a maximum bottom width of 10 feet. If the required bottom width is greater than 10 feet, parallel biofilters should be used in conjunction with a device that splits the flow and directs the proper amount to each biofilter.

- **Step 5** - Calculate the cross sectional area of flow for the given channel using the calculated bottom width and the selected side slopes and depth.
- **Step 6** - Calculate the velocity of flow in the channel using: $V = Q / A$

  If V is less than or equal to 1 ft/sec, the biofilter will function correctly with the selected bottom width. Proceed to design step 7.

  If V is greater than 1 ft/sec, the biofilter will not function correctly. Increase the bottom width, recalculate the depth using Manning's Equation and return to Step 5.
- **Step 7** - Select a location where a biofilter with the calculated width and a length of 200 feet will fit. If a length of 200 feet is not possible, the width of the biofilter must be increased so that the area of the biofilter is the same as if a 200 foot length had been used.
- **Step 8** - Select a vegetation cover suitable for the site. Consult the local NRCS office or the County Extension Service for guidance.
- **Step 9** - Determine the peak flow rate to the biofilter during the 25-year 24-hour storm (a 10-year storm is acceptable, provided that reparative maintenance will be performed following every 10-year event). Using Manning's Equation, find the depth of flow (typically, $n = 0.04$ during the 25-year flow; n may need to be adjusted if a 10-year event is used). The depth of the channel shall be 1 foot deeper than the depth of flow. Check to determine that shear stresses do not cause erosion; the velocity needs to stay below 2 ft/sec. This step can be skipped if all storms larger than the short duration water quality storm bypass the biofiltration swale.

Construction and Maintenance Criteria

- Groomed biofilters planted in grasses shall be mowed during the summer to promote growth and pollutant uptake.
- Remove sediments during summer months when they build up to 4 inches at any spot, cover biofilter vegetation, or otherwise interfere

with biofilter operation. Reseed bare spots created by removal equipment.

- Inspect biofilters periodically, especially after periods of heavy runoff. Remove sediments, fertilize, and reseed as necessary. Be careful to avoid introducing fertilizer to receiving waters or ground water.
- Clean curb cuts when soil and vegetation buildup interferes with flow introduction.
- Remove litter to keep biofilters free of external pollution.

See Appendix 5A for more detailed information.

BMP T5.50 Vegetated Filter Strip

A vegetated filter strip is a facility that is designed to provide stormwater quality treatment of conventional pollutants but not nutrients. See Figure 5.5.2. This BMP will not provide stormwater quantity control. Vegetated filter strips are primarily used adjacent and parallel to paved areas such as parking lots or driveways, and along rural roadways where sheet flow from the paved area will pass through the filter strip before entering a conveyance system or a quantity control facility, or is dispersed into areas where it can be infiltrated or evaporated. The vegetated filter strip is still in an interim phase of development. This BMP is acceptable for use on any project that meets the General Criteria listed below; however, the General Criteria may change in the future as research projects and field tests involving this BMP are completed.

UIC regulations do not apply to these facilities (see section 5.6).

General Criteria

- Along roadways, filter strips should be placed at least 1 foot, and preferably 3 to 4 feet from the edge of pavement, to accommodate a vegetation free zone.
- Once stormwater has been treated by a filter strip, it may need to be collected and conveyed to a stormwater quantity BMP.
- The flow from the roadway must enter the filter strip as sheet flow.
- Vegetated filter strips must not receive concentrated flow discharges.
- A maximum flowpath of each 30 feet can contribute to a filter strip designed via this method.
- Filter strips should be used where the roadway ADT is less than 30,000.
- Vegetated filter strips should not be used on roadways with longitudinal slopes greater than 5 percent because of the difficulty in maintaining the necessary sheet flow conditions.

- Vegetated filter strips should be constructed after other portions of the project are completed.
- Use of this BMP may be limited to crowned roads where filter strips can be added along both sides of the road. It should not be used for banked roads that drain solely to one side without additional analysis to account for the extended flowpath length.

Design Procedure This procedure is based on the Narrow Area Filter Strips presented in the 1998 King County Surface Water Design Manual. The sizing of the filter strip is based on the length of the flowpath draining to the filter strip and the longitudinal slope of the filter strip itself (parallel to the flowpath).

- **Step 1: Determine length of flowpath draining to the filter strip.** Determine the length of the flowpath from the upstream to the downstream edge of the impervious area draining to the filter strip. Normally this is the same as the width of the paved area, but if the site is sloped, the flow path may be longer. In the case of crowned roadways, the flowpath may be half the width of the roadway.
- **Step 2: Determine average longitudinal or cross slope of the filter strip:** Calculate the longitudinal or cross slope of the filter strip (parallel to the flowpath), averaged over the total width of the filter strip. If the slope is less than 2 percent, use 2 percent for sizing purposes. The maximum longitudinal or cross slope allowed is 6:1 or 17 percent.
- **Step 3: Determine required length of the filter strip:** Use Figure 5.5.1 or an approach based on determining the hydraulic residence time of runoff, to size the filter strip. To use the figure, find curve representing the appropriate length of the flowpath (interpolate between curves as necessary; identifying appropriate filter strip lengths for flowpaths longer than 30’ may require additional analysis for practical application – see General Criteria above, last bullet). Find the point along the curve where the design longitudinal or cross slope of the filter strip is directly below and read the filter trip length to the left on the y axis. Note that the minimum required filter strip length is: 4’ for a 10’ flowpath; 4.5’ for a 25’ flowpath; and 5.5’ for a 30’ flowpath. The filter strip must be designed to provide this minimum length “L” along the entire stretch of pavement draining to it.

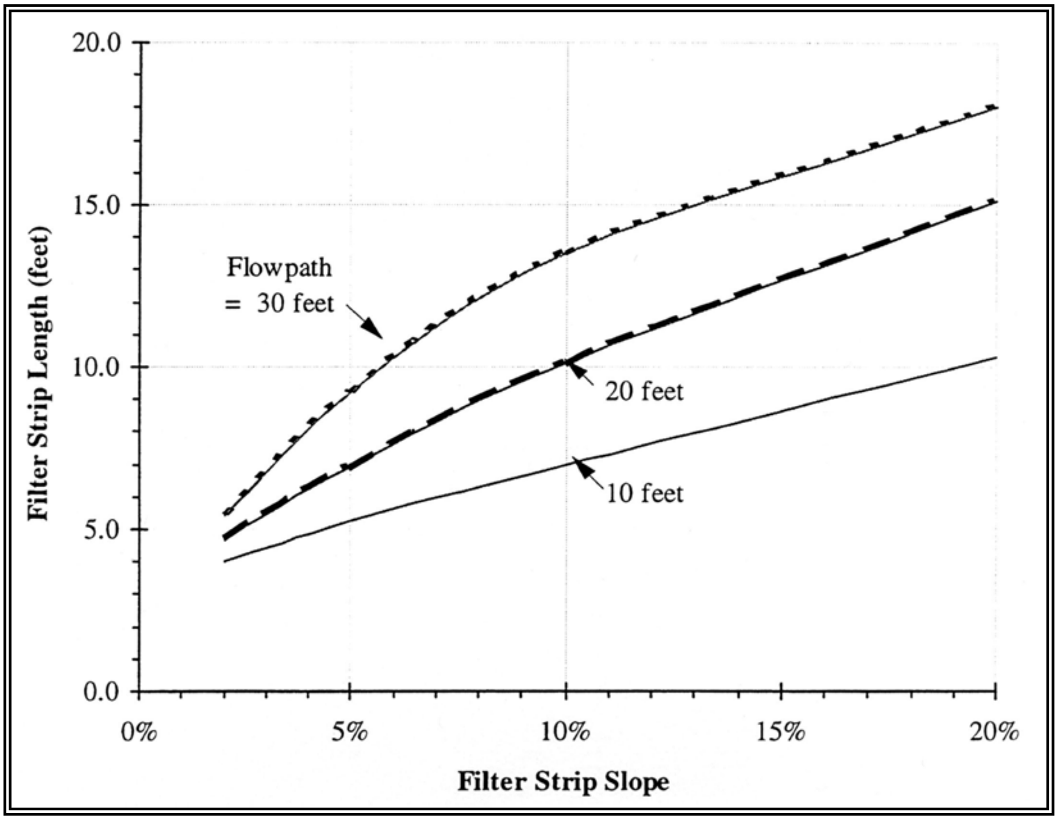
Construction and Maintenance Criteria

- Construct filter strips after completion of paving operations.
- Groomed filter strips planted in grasses should be mowed during the summer to promote growth.
- Inspect filter strips periodically, especially after periods of heavy runoff. Remove sediments and reseed as necessary. Catch basins or

sediment sumps that precede filter strips should be cleaned to maintain proper function.

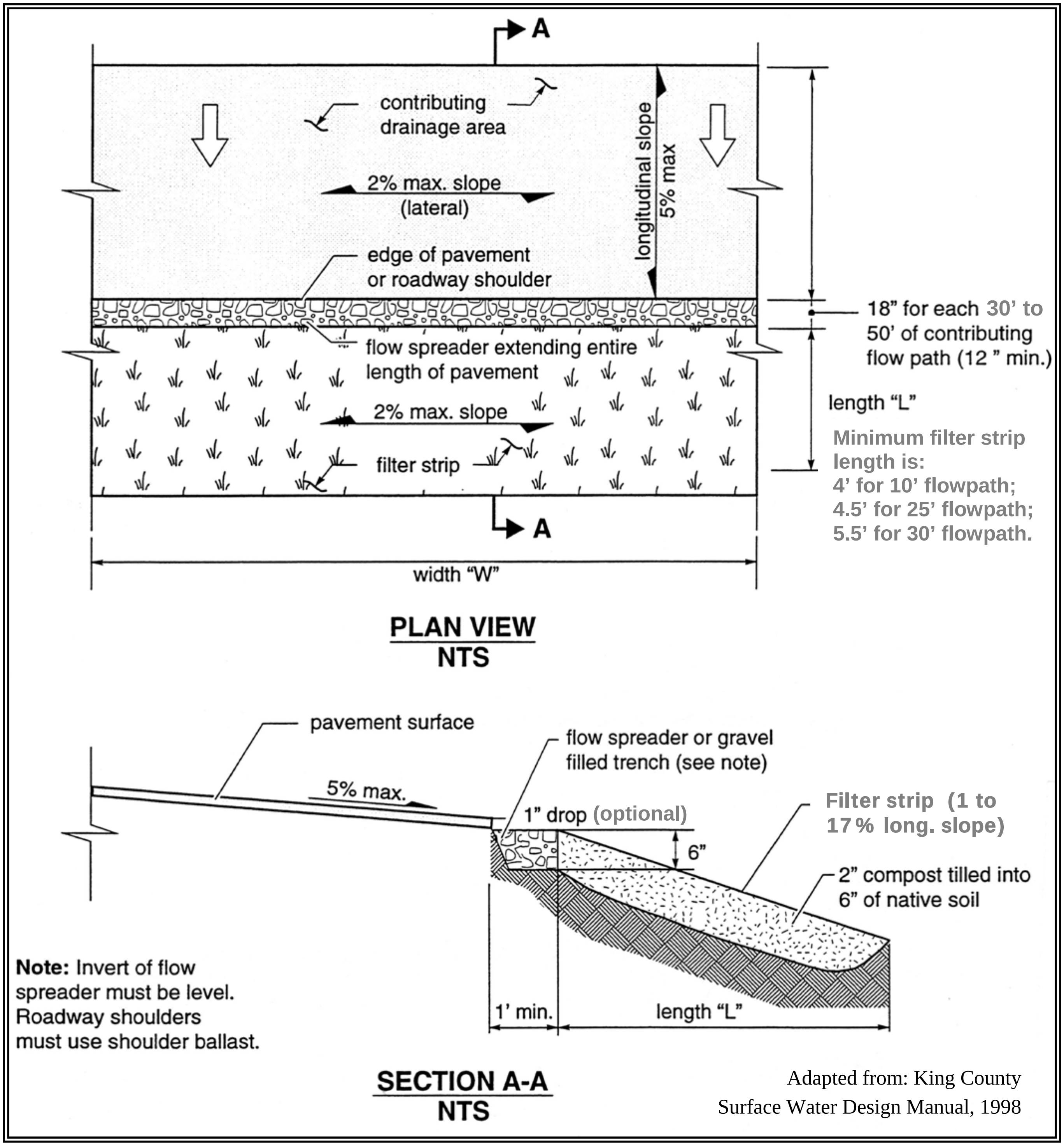
See Appendix 5A for more detailed information.

Figure 5.5.1 Vegetated Filter Strip (design graph)



Source: King County Surface Water Design Manual, 1998

Figure 5.5.2 Typical Vegetated Filter Strip (details)



5.6 Subsurface Infiltration (Underground Injection Facilities)

***Note:** This section provides **interim guidance** for projects disposing of stormwater using facilities regulated under the Underground Injection Control (UIC) program. At publication, final technical guidance was under development in a statewide process parallel to Ecology's revision of Washington State's UIC rule. When the rule is completed and the final technical guidance is published, this section may be superseded all or in part by that guidance. See Ecology's website at* www.ecy.wa.gov/programs/wq/grndwtr/uic *for information and updates on the UIC rule revision.*

5.6.1 Purpose and Definitions

Subsurface infiltration is one of the preferred methods for disposing of excess stormwater in order to preserve natural drainage systems in eastern Washington. Subsurface infiltration is regulated by the Underground Injection Control (UIC) rule, which is intended to protect underground sources of drinking water. By definition, a UIC facility includes a manmade subsurface fluid distribution system, which means an assemblage of perforated pipes, drain tiles, *or* other similar mechanisms intended to infiltrate fluids into the ground *or* a dug hole that is deeper than the largest surface dimension. Buried pipe and/or tile networks that serve to collect water and discharge that water to a conveyance system or to surface water are not UIC facilities. For the purposes of this section, subsurface infiltration systems include drywells, pipe or french drains, drain fields and other similar devices that are designed to discharge stormwater directly into the ground. Many of these UIC facilities are designed to infiltrate the 10- or 25-year runoff event within a 48 to 72 hour period; check for local requirements.

The following types of stormwater infiltration facilities are not subject to the UIC rule: surface infiltration basins as described in BMP F6.21 and flow dispersion as described in BMPs F6.40, F6.41, F6.42 and T5.30. This section of the Manual does not apply to those facilities or methods of stormwater disposal.

The UIC rule does apply to some designs of infiltration trenches as described in BMP F6.22 that include perforated pipe. Those facilities must be registered with the Department of Ecology (see Section 5.6.7). However, those facilities must be designed, constructed, operated, and maintained according to the specifications of this Manual or another equivalent manual approved by Ecology in order for the facilities to be rule authorized (no permits needed). This section does not apply to those facilities except for the registration requirement.

The majority of UIC facilities receiving stormwater discharges can be authorized by the UIC rule without requiring individual permits where the discharge, the site, and the structure of the facility meet the requirements detailed in this section. (Surface infiltration trenches that are designed, constructed, operated, and maintained according to the specifications in BMP F6.22 of this Manual or in another equivalent manual approved by Ecology are also authorized by the UIC rule.) Facilities that cannot meet the requirements of this section must apply for individual permits from the Department of Ecology. In some cases, the discharge may be prohibited. See Section 1.3.4 for more information on the UIC rule-authorization basis and requirements.

The unsaturated geologic material between the bottom of the infiltration facility and the top of an unconfined aquifer, called the vadose zone, usually provides some level of treatment by removing contaminants by filtration, adsorption, and/or degradation. In some cases, the treatment provided by the vadose zone is suitable for protecting groundwater quality from contamination by stormwater runoff; in other cases, additional pre-treatment may be required to protect groundwater quality. This section defines site suitability, pre-treatment requirements, and design criteria for UIC rule-authorized discharges of stormwater to subsurface infiltration systems, including drywells.

This section does not apply to any UIC facilities that receive fluids other than stormwater (precluding accidental spills and illicit discharges, addressed in Section 5.6.4).

This section does not address the infiltration capacity of the vadose zone below the UIC facility, nor does it address the ability of the facility to meet local operational requirements to infiltrate a certain volume of water in a given amount of time.

5.6.2 Application and Limitations

Subsurface infiltration (UIC facilities) may be used to provide flow control of excess stormwater runoff where pollutant concentrations that reach groundwater are not expected to exceed Washington State groundwater quality standards; for flows greater than the water quality design storm (see Section 2.2.5); or where stormwater is adequately treated prior to discharge. Under certain conditions, subsurface infiltration may be considered to provide an acceptable level of treatment for removing pollutants from stormwater that exceed groundwater quality standards.

Rationale and evaluation criteria for authorization by rule: These criteria apply only to discharges of stormwater runoff to (and from) UIC facilities. The technical guidance for managing stormwater discharges to groundwater was developed using a risk-based approach. In order to be rule authorized, the discharge from a UIC structure must meet the "non-endangerment standard," which requires that the discharge comply with state groundwater quality standards when it reaches the water table, or first comes into contact with an aquifer (see Section 1.3.4 and WAC 173-200).

Potential Contaminants in Stormwater Runoff

A review of available urban and road runoff data (see Section 1.2.1 for additional detail and references) indicates that typical concentrations of copper, zinc, total suspended solids, chloride, and phosphorus in urban and road runoff do not generally appear to be an issue of concern for meeting Washington State groundwater quality standards. Phosphorus in groundwater may still be a concern in small lake watersheds. Chromium, lead, iron, and arsenic are potential pollutants of concern: if the suspended portion is removed by filtration, the typical dissolved fractions of the total concentrations of these metals in urban and road runoff are expected to meet state groundwater quality standards except for arsenic, which is naturally present at levels of concern in groundwater in many areas of Washington State. Oil, grease and PAHs are of potential concern, particularly in the event of a large spill reaching an unprotected UIC facility. Pollutants such as pesticides and nitrates may be a concern in areas where landscapes are intensively managed. Concentrations of fecal coliform in urban and road runoff commonly exceed groundwater quality standards and may exceed the capacity of the vadose zone to remove bacteria to a level that meets standards; however, no stormwater treatment technology currently exists to practically address this issue.

Potential Removal of Contaminants by the Vadose Zone

Studies of sub-surface infiltration systems indicate that filtered and adsorbed pollutants accumulate in the vadose zone at depths of less than a few feet below the facilities at concentrations that may require soil cleanup activities upon decommissioning of a UIC facility (Mikkelsen et al 1996 #1 and #2; Appleyard 1993). Because contaminated soil removal and disposal costs can be considerable, project proponents may wish to consider including pre-treatment facilities to remove solids from stormwater runoff and avoid potential cleanup requirements following long-term use of the UIC facility. This caution is particularly addressed to UIC facilities receiving runoff from traffic areas with moderate to high use.

Studies of pollutant concentrations in water through and below infiltration systems show mixed results in the effectiveness of vadose zone filtration in protecting groundwater quality (USEPA 1999; Pitt 1999; Mason et al 1999; and Appleyard 1993). Many of the problems documented in these studies can be corrected by proper siting, design, and use of the facilities; enhanced source control; additional pre-treatment prior to discharge to the facilities; or prohibition of the discharge. The remainder of this section details guidance intended to ensure that UIC facilities are properly sited, designed, and operated to protect water quality.

Presumptive versus Demonstrative Compliance with the Rule

Project proponents may choose to follow either a presumptive or demonstrative approach to compliance with the UIC rule:

- The *presumptive* approach to protecting groundwater quality is defined as using the methods described in this section. This approach considers potential pollutant loading (based on the pollutant loading expected in storm runoff from a given land use or activity) and the treatment capacity of the vadose zone (based on subsurface geology and the thickness of the best naturally present matrices for removing pollutants).
- A *demonstrative* approach to protecting groundwater quality may consider site specific information that modifies either the pollutant loading category or the treatment capacity of the vadose zone or both for a stormwater discharge to a subsurface infiltration system. A demonstrative approach to protecting groundwater quality may also utilize a site specific analysis that otherwise demonstrates that the proposed discharge will comply with groundwater quality standards. Local governments might also modify the presumptive approach to protecting groundwater quality based on local information and planning that results in adoption of a UIC management plan that meets the non-endangerment standard.

The presumptive approach described in this section is based primarily on benefits provided by removal of the solid phase of pollutants in stormwater as it passes through the vadose zone. In almost all cases, removal of the solid phase of metals and most pesticides from stormwater results in meeting the groundwater standards. Filtration and separation are considered the most effective means of removing fecal coliform.

Necessary Source Control Activities

Additional, programmatic or source control activities may be necessary to protect groundwater from soluble pesticides, nitrates, and road salts and other anti-icers and deicers. To the maximum extent practicable, exposure of stormwater to these chemicals must be reduced by one or more of the following: a reduction in application rate or more selective use; increased source control activities; or separation of the areas of use from the contributing area draining to the UIC facility. Contact the local jurisdiction to determine whether specific source control requirements apply to your project in addition to those methods described in Chapter 8 for the proposed land use.

5.6.3 Siting Criteria and Treatment Requirements

Prior to evaluation of the water quality considerations, project proponents should be certain that the site meets the criteria in Section 6.3.5 of this Manual or appropriate alternative local criteria.

Where geologic and groundwater depth information are available, Tables 5.6.1 through 5.6.3 can be used to evaluate whether a stormwater discharge from a commercial or residential site to a UIC facility meets the non-endangerment standard. Industrial sites with no outdoor processing, storage, or handling of raw or finished products may also use these tables; additional guidance for industrial sites is provided later in this sub-section (see “Land uses or activities with special treatment requirements”). Used together, the tables identify the extent to which the vadose zone may be presumed to provide sufficient treatment for a given pollutant loading surface in order to meet groundwater quality standards (see also the exceptions to Table 5.6.3 in the text sections below). At sites where the vadose zone is considered to provide sufficient treatment to protect groundwater quality (“Suitable for all UIC facilities” or “Suitable for 2-stage drywell” in Table 5.6.3), pre-treatment is not required. If the proposed UIC facility cannot meet the depth/thickness requirements in Table 5.6.1 or in the exceptions below, the design must include pre-treatment for removal of solids. All high category pollutant loadings must provide pre-treatment for removal of oil. All project proponents should read Sections 5.6.4 Accidental Spills and 5.6.5 Prohibitions for additional considerations that may apply to their sites.

Tables 5.6.1 through 5.6.3 are intended for use in meeting the presumptive approach; project proponents and local jurisdictions using the demonstrative approach may define other treatment capacity categories and pollutant loading requirements.

Table 5.6.1 – Treatment capacity of vadose zone materials (subsurface geologic matrix below the facility and above an unconfined aquifer) for removing contaminants from stormwater discharged to UIC facilities.

Presumed treatment capacity and conditions	Description of vadose zone layer
HIGH A minimum thickness of <u>ten feet</u> of these materials must be naturally present between the bottom of the UIC structure and the top of the highest known seasonal water table. *	Materials with average grain size <0.125mm *or* having a sand to silt/clay ratio of less than 1:1 and sand plus gravel less than 50% Lean, fat, or elastic clay Sandy or silty clay Silt Clayey or sandy silt Sandy loam or loamy sand Silt/clay with inter-bedded sand Well-compacted, poorly-sorted materials *This category generally includes till, hardpan, caliche, and loess*
MEDIUM A minimum thickness of <u>fifteen feet</u> of these materials must be naturally present between the bottom of the UIC structure and the top of the highest known seasonal water table.*	Materials with average grain size 0.125mm to 4mm *or* having a sand to silt/clay ratio between 1:1 and 9:1 and percent sand greater than or equal to percent gravel Fine, medium or coarse sand Gravelly sand Sand with inter-bedded clay and/or silt Poorly-graded/sorted, silty or muddy gravel Poorly-compacted, poorly-sorted materials *This category includes most outwash deposits, non-cavernous limestone, and some alluvium*
LOW A minimum thickness of <u>fifty feet</u> of these materials must be naturally present between the bottom of the UIC structure and the top of the highest known seasonal water table.	Materials with average grain size >4mm to 64mm *or* having a sand to silt/clay ratio greater than 9:1 and percent sand less than percent gravel Well-graded/sorted or clean gravel Sandy gravel *or* sand and gravel *This category includes some alluvium and outwash deposits*
NONE	Materials with average grain size >64mm *or* having total fines (sand and mud) less than 5% Boulders and/or cobbles Fractured rock *This category generally includes fractured basalt, other fractured bedrock, and cavernous limestone*

* See Section 5.6.3 narrative for possible exceptions to the thickness requirement. Note that this table does not address the matrix within which the facility is constructed.

Table 5.6.2 – Stormwater pollutant loading classifications for UIC facilities receiving stormwater runoff.

Pollutant loading classification	Proposed land use or site characteristics*
Insignificant	Impervious surfaces not subject to motorized vehicle traffic or application of sand or deicing compounds Un-maintained open space
Low	Urban roads with ADT <7,500 vehicles per day Rural roads, freeways, and highways with limited access control with ADT <15,000 vehicles per day Parking areas with <40 trip ends per 1,000 SF of gross building area or <100 total trip ends (e.g., most residential parking and employee-only parking areas for small office parks or other commercial buildings) Most public parks (see prohibitions for exceptions) Roofs that are subject only to atmospheric deposition and normal heating, ventilation, and air conditioning system outputs Other land uses with similar traffic/use characteristics
Medium	Urban roads with ADT between 7,500 and 30,000 vehicles per day Rural roads, freeways, and highways with limited access control with ADT between 15,000 and 30,000 vehicles per day Parking areas with between 40 and 100 trip ends per 1,000 SF of gross building area or between 100 and 300 total trip ends (*e.g.* visitor parking for small to medium commercial buildings with a limited number of daily customers) Primary access points for high-density residential apartments Most intersections controlled by traffic signals Transit center bus stops Some high density residential roads and parking areas Roofs that are subject to ventilation systems that are specifically designed to remove commercial indoor pollutants Other land uses with similar traffic/use characteristics
High	All roads with ADT >30,000 vehicles per day High-density intersections (see definition in Chapter 2.2.5) Parking areas with >100 trip ends per 1,000 SF of gross building area or >300 total trip ends (e.g., commercial buildings with a frequent turnover of visitors, such as grocery stores, shopping malls, restaurants, drive-through services, etc.) On-street parking areas of municipal streets in commercial and industrial areas Highway rest areas Other land uses with similar traffic/use characteristics

* See Section 5.6.5 prohibitions. Average daily traffic count (ADT) and trip ends must be calculated for the design life of the project and may be determined using "Trip Generation" published by the Institute of Transportation Engineers.

Table 5.6.3 – Matrix for determining suitability of subsurface discharge of stormwater from commercial and residential land uses to new UIC facilities

(See tables 5.6.1 and 5.6.2 for treatment capacity and pollutant loading definitions. All project proponents should read the entirety of Section 5.6 for exceptions or other requirements that apply in certain situations. Appropriate pre-treatment requirements must be determined using the information provided in Section 5.2 and in this section.)

Treatment capacity / **Pollutant loading**	*High*	*Medium*	*Low*	*None*
Insignificant	Suitable for all UIC facilities	Suitable for all UIC facilities	Suitable for all UIC facilities	Suitable for all UIC facilities
Low	Suitable for all UIC facilities	Suitable for all UIC facilities	Suitable for all UIC facilities	Pretreatment required to remove solids [4]
Medium	Suitable for two-stage drywells [2]	Suitable for two-stage drywells [2]	Pretreatment required to remove solids [4]	Pretreatment required to remove solids [4]
High [1]	Pretreatment required to remove oil [3]	Pretreatment required to remove oil [3]	Pretreatment required to remove oil and solids [3,4]	Pretreatment required to remove oil and solids [3,4]

[1] Note that the prohibitions listed in Section 5.6.5 still apply.

[2] A two-stage drywell includes a catch basin or spill control structure that traps small quantities of oils and solids; the spill control device may be a turned-down pipe elbow or other passive device like the one shown in Figure 5.10.3.

[3] Treatment to remove oil means oil control as defined in Section 2.2.5 and Section 5.2.

[4] Treatment to remove solids means basic treatment as defined in Section 2.2.5 and Section 5.2. Removal of solids should also remove a large portion of the metals in most stormwater runoff.

Evaluation of the Treatment Capacity of the Vadose Zone

Several alternative approaches are provided in Table 5.6.1 for identifying the proper treatment capacity classification of the vadose zone matrix. The designer can utilize grain size distribution and/or ratios, typical categories assigned by well drillers, and(or) geologic names. Geologic materials have been classified as having high, medium, low, or no treatment capacity. Keep in mind that the focus of this table is on a treatment layer, and not the depth to groundwater or the matrix within which the facility is constructed.

Native materials in the "high treatment capacity" category provide filtration combined with some chemically reactive characteristics, specifically cation exchange capacity. Native organic matter improves adsorption and filtration (Igloria et. al, 1997) but is rarely found at depths below UIC facilities, so this category generally relies on clay or fine silt materials to provide chemical reactivity. These may be mixtures of materials where silt and clay fill the pore spaces in matrix the coarser materials; the more compacted, the better the filtration.

Native materials in the "medium treatment capacity" category provide moderate to high filtration and have minor or no chemically reactive characteristics. Native materials in the "low treatment capacity" category provide some minimal filtration; the sand and gravel mixtures in this category may provide moderate filtration when a UIC facility is initially installed, but will typically yield preferential flow paths where treatment capacity is reduced. Materials in the "no treatment capacity" category do not provide filtration to remove pollutants.

Subsurface Geologic Data

Geologic information may be available from regional subsurface geology maps in publications from the Department of Natural Resources or U.S. Geological Survey, from a well borehole log(s) in the same quarter section on the Department of Ecology website, or from local governments. Surface soils maps generally do not provide adequate information, although the parent material information provided may be helpful in some locations. Well borehole log locations should be verified, as electronic data bases contain many errors of this type. When using borehole logs, a "nearby" site is generally within a quarter of a mile. Subsurface geology can vary considerably in a very short horizontal distance in many areas of the state, so professional judgment should be used to determine whether the available data are adequate or site exploration is necessary. Where reliable regional information or nearby borehole logs are not readily available, it will be necessary to obtain data through site exploration. Alternatively, for small projects where site exploration is not cost-effective, a design professional might apply a conservative design approach subject to the approval of the local jurisdiction.

Depth to Groundwater

Groundwater depths may be available from Department of Ecology, Department of Natural Resources, or U.S. Geological Survey publications; or from local governments. Knowledge of the seasonal high water table is especially important for siting UIC facilities in areas with very shallow water tables (less than ten to fifteen feet below the bottom of the UIC facility), since significant mounding of infiltrating stormwater can occur above the water table (Appleyard, 1993) and UIC facilities must not discharge stormwater directly into groundwater at any time (perched lenses excepted), even if the groundwater level is rising in response to the UIC discharge.

Water level information is also needed to confirm the thickness of the treatment layer in the vadose zone between the bottom of the UIC facility and the highest known groundwater level. Water level data associated with a single borehole log may be insufficient to determine the seasonal high water table, especially if the drilling occurred outside of the normal period of highest water tables (generally late winter through mid-spring in most of Washington State; but keep in mind that at sites in heavily irrigated areas, the seasonal high water table elevation may occur in late summer) and(or) following a wet season with lower than normal precipitation. At sites where the fluctuation of the seasonal water table is large (several feet) or unknown, designers should err on the side of caution: UIC facilities must not discharge stormwater directly into groundwater. The minimum required separation between the bottom of the facility and the highest seasonal water table depends upon the characteristics of the vadose zone, the potential for mounding of infiltrating stormwater above the water table, and the degree of certainty of available data as to the seasonal high water table elevation.

Well-head Protection

All UIC facilities must be sited in accordance with state or local Department of Health guidance and requirements. In particular, UIC facilities must be located the minimum required horizontal and(or) vertical distance from drinking water supply wells as required by the Department of Health. The current state regulation requires 100 feet of horizontal separation; local departments may establish stricter requirements and vertical separations, and data indicate bacteria can be transported more than 100 feet through some medium and all low treatment capacity media (Robertson and Edberg, 1997; Ehrlich and others, 1979). Contact your local jurisdiction for information about well-head protection areas. Project proponents should consider available information about the direction of local groundwater movement, time of travel, and vulnerability of drinking water supply wells to contamination when siting UIC facilities. Other setbacks may be required by local code, and some guidance regarding siting of stormwater facilities near geologic hazards is provided in Chapter 3.

As noted in Section 5.6.2 above, project proponents may wish to consider including pre-treatment facilities to remove solids from stormwater runoff and avoid potential cleanup requirements following long-term use of any UIC facility receiving runoff from traffic areas, regardless of the pollutant loading classification.

Exceptions Based on Site-Specific or Local Studies

Exceptions to Tables 5.6.1 through 5.6.3:

Where more or better site-specific data are gathered by the project proponent and local permission is granted, or where a local planning study is done with the intent of modifying the presumptive approach described in this section, the following modifications to the tables may be made:

- Where reliable, on-site information is available or where borehole logs exist for sites within one-quarter mile of the proposed UIC facility and local geology does not vary greatly, discharge of stormwater with *insignificant* or *low* pollutant loadings to a UIC facility above a vadose zone containing as little as three feet of a *high-capacity* treatment matrix thickness or ten feet of a *medium-capacity* treatment matrix thickness is allowed if implemented under a locally developed UIC management plan. Site specific water level data must be collected to justify the minimal separation from the water table if the three feet of high-capacity treatment matrix provide the entire separation between the bottom of the structure and the seasonal high water table; evaluation of the potential for mounding of infiltrating stormwater above the water table should also be considered.
- Where reliable, on-site information is available or where borehole logs exist for sites within one-quarter mile of the proposed UIC facility and local geology does not vary greatly, discharge of stormwater with *medium* or *high* pollutant loadings to a UIC facility above a vadose zone containing as little as six feet of a *high-capacity* treatment matrix thickness is allowed if implemented under a locally developed UIC management plan. Site specific water level data must be collected to justify the minimal separation from the water table if the six feet of high-capacity treatment matrix or ten feet of medium-capacity treatment matrix provide the entire separation between the bottom of the structure and the seasonal high water table; evaluation of the potential for mounding of infiltrating

stormwater above the water table should also be considered. Use of a two-stage drywell (including spill control or a catch basin) is still required for *medium* pollutant loadings and pre-treatment for oil control is still required for *high* pollutant loadings.

- Where source control methods approved by the local jurisdiction or other pre-treatment requirements will eliminate or significantly reduce target pollutants from *high* or *medium* pollutant loadings and a local ordinance or other regulatory mechanism exists to enforce the source control activity as a requirement, the local jurisdiction may accept reclassification of these sites as medium or low, respectively.
- Where local jurisdiction planning efforts result in an alternative framework for evaluating the suitability of various discharges to UIC facilities, that approach may be used in lieu of Tables 5.6.1-5.6.3. Such an approach must be judged by the local jurisdiction to meet the non-endangerment standard for protecting groundwater under the local conditions. Other special conditions and exceptions listed in this subsection and in the subsections below on land uses or activities with special treatment requirements still apply.

Exceptions Based on Environmental Conditions

<u>UIC facilities located near surface water bodies that do not meet state water quality standards</u>: Where a UIC facility discharges to groundwater that contributes to baseflow in a nearby surface water body which does not meet state water quality standards for metals, fecal coliform, and(or) phosphorus, the potential of the subsurface discharge to the UIC facility to contribute to the continued violation surface water quality standards must be considered. Shoreline regulations may also apply. Specific requirements are listed below.

- Where a UIC facility receives stormwater from a *medium* or *high* pollutant loading source area and discharges to a shallow water table (less than ten to fifteen feet below the bottom of the UIC facility) and it is less than 100 feet from a surface water body which is impaired due to **metals**, pre-treatment for solids removal is required. If the UIC facility is already required to apply pre-treatment for solids removal to protect the groundwater due to the expected pollutant load and(or) the limited treatment capacity of the vadose zone materials, then additional pre-treatment for metals removal is also required (see Section 2.2.6 and/or Section 5.2).
- Where a UIC facility discharges to a shallow water table (less than 10 to 15 feet below the bottom of the UIC facility) and is less than 100 feet from a surface water body is impaired due to

coliform bacteria, then pre-treatment for solids removal is required. This pre-treatment requirement extends to UIC facilities up to one quarter mile from the surface water where the treatment capacity of the vadose zone is categorized as "low" or "none."

- Where a UIC facility is located near a surface water body which is impaired due to **phosphorus**, pre-treatment for removal of phosphorus may be required according to the remediation strategy adopted in a TMDL or other water cleanup plan. Check with the local jurisdiction for applicable requirements. If required, see Chapter 6.2 for more information.

Special Treatment Requirements

Land uses or activities with special treatment requirements:

- Where **fueling activities take place or petroleum products are stored and(or) transferred** in amounts greater than 1,500 gallons per year, the UIC facility must include a spill containment structure. A spill prevention, control, and containment plan is also required for these sites (see Chapter 3).
- At all other **high-use sites** (see the definition in Section 2.2.5), the UIC facility must include a spill control device, such as a turned-down pipe elbow or other passive device like the one shown in Figure 5.10.3.
- At sites with stormwater associated with **industrial** activities as defined by EPA (40 CFR 122.26(b)(14)), pre-treatment for solids removal is required prior to discharge to a UIC facility where **outdoor processing, handling, or storage of raw solid materials or finished products**, including outdoor loading areas for these materials or products, takes place. Stormwater associated with construction activities at sites classified as Category (x) under the federal rules are exempt from this requirement. If any activities at the facility fall under categories that are subject to benchmark monitoring requirements for nitrate, nitrite, ammonia, or phosphorus under in the U.S. Environmental Protection Agency's multi-sector industrial permit (October 30, 2000), runoff from the site must be directed to biofiltration or bioinfiltration systems or to constructed wetlands with pre-treatment for removal of solids, or to sanitary sewer if allowed by the local jurisdiction. Facilities may complete a "no exposure" certification as part of Ecology's UIC facility registration process to be exempted from these requirements; in order to qualify, no outdoor processing, handling, or storage of raw solid materials or finished products may take place at the facility.

- At **commercial** sites with **outdoor handling or storage of raw solid materials or treated wood products**, pre-treatment for solids removal is required prior to discharge to a UIC facility.
- Due to intensive fertilizer and pesticide use and the ineffectiveness of treatment facilities to remove those pollutants from runoff, UIC facilities should not be located at **intensely managed landscape areas** such as golf courses, public ball fields, and cemeteries, where pesticides and(or) fertilizers are heavily applied. Runoff from the landscape areas should be directed to biofiltration or bioinfiltration systems or to constructed wetlands prior to discharge to UIC facilities. Limiting use of applied chemicals at these sites is encouraged, as is site design that minimizes runoff from the landscaped surface.
- Due to the ineffectiveness of stormwater treatment facilities in removing nutrients from runoff, UIC facilities may not be located at **sites that generate high nutrient loadings in runoff**. Runoff from sites with high nutrient loadings should be directed to biofiltration or bioinfiltration systems or to constructed wetlands prior to discharge to UIC facilities, or used to irrigate crops in accordance with other applicable requirements.

Note that UIC facilities may still be employed for parking lots and other impervious areas at these sites in accordance with Tables 5.6.1-5.6.3.

Pre-Treatment Methods

<u>Selection of pre-treatment BMPs</u>: Where structural pre-treatment BMPs are required, the appropriate treatment BMPs must be selected from other sections in this chapter or from an equivalent manual approved by Ecology. (Source Control BMPs are described in Chapter 8.) Project proponents may also request conditional approval from Ecology for a new or experimental treatment method (see Chapter 5.12 Emerging Technologies). The BMPs and source control activities must be designed to remove or attenuate the target pollutants to levels that, following additional treatment through the vadose zone, will comply with state groundwater quality standards when the discharge reaches the water table, or first comes into contact with an aquifer (see Chapter 1.3.4 and WAC 173-200).

These BMPs include filtration and bio-infiltration BMPs; water quality vaults and wetpools; oil/water separators; manufactured devices (such as catch basin inserts, media filters and other emerging technology); and other approved facilities that provide treatment of expected pollutants (using filtration, adsorption, or sedimentation processes) for flows up to the water quality design storm (see Section 2.2.5).

Overflows or bypass flows from these treatment BMPs may be discharged directly to UIC facilities, provided that the entire water quality design storm flow is treated and that only the excess flows are routed directly to the drywell and discharged without treatment. Such discharge is allowed only provided that the frequency of overflow and the combination of site characteristics and expected pollutant loadings (based on projected land use) are not likely to result in contamination of groundwater.

5.6.4 Accidental Spills and Illicit Discharges

All impervious surfaces contributing stormwater to UIC structures should be qualitatively evaluated for risk of exposure to potential spills. For traffic surfaces, the designer should consider whether any of the following conditions are present: the bottom of a steep hill, a dangerous intersection, sharp turn in a road or other locations where traffic accidents are likely to occur; roads in industrial areas or with frequent daily travel by tanker trucks; or some other increased risk situation that might increase the potential for accidental spills. For commercial and industrial sites, the designer should consider the types of materials that will be handled and stored at the site; site layout and spill response plans; and probable employee training and preparation for responding to a spill and protecting the UIC facility from receiving the spilled material. In general, response to spills on roadways will be delayed, but response to an on-site spill at a well-prepared facility can be almost immediate.

If in the designer's judgment spills are likely during the life of the project, the UIC facility should include a spill containment structure or spill control device (see Chapter 8). The owner/operator should regularly inspect the facility in order to detect and attend to any unreported spills that may have occurred. All spills must be reported to Ecology.

It is preferable to prevent any spill from passing through the UIC facility and entering the vadose zone. If the potential for accidental spills is judged to be low and no spill containment structure or control device is present, or if the project proponent chooses to accept responsibility for cleanup and retrofit of the facility following a spill, the vadose zone may be used temporarily to contain a spill. A minimum of 10 feet and preferably 15 feet of separation between the bottom of the drywell and the top of an unconfined aquifer is deemed necessary to protect groundwater from most accidental or illicit spills that might occur on surfaces that drain to UIC structures. Regardless of the identified risk, in the event that a spill occurs and spreads through the vadose zone, the owner/operator must remove and properly dispose of the contaminated soils and replace them with clean materials as soon as practicable. In general, depths greater than 25 feet are difficult to clean up with soil removal equipment. If removal of deeper contaminated sediments is not practicable, long-term monitoring of the groundwater or application of other cleanup technologies may be required.

Areas or land uses that local jurisdictions determine to be subject to frequent spills or illegal dumping may be prohibited from using UIC facilities. Historic incidents in these areas may have been documented by the local jurisdiction, or there may be sufficient evidence to identify the location as an attractive nuisance. For example, UIC facilities at many auto parts shops, restaurants, and food processing facilities have been subject to frequent illicit discharges by customers or employees. Designers planning stormwater infrastructure for such facilities should discuss the potential problems with their clients and take care to locate UIC facilities in such a manner as to minimize easy, unobtrusive access for illegal dumping. Employee training will help to reduce these incidents.

5.6.5 Prohibitions

Due to potential contamination of groundwater, discharge of stormwater to UIC facilities is not allowed where any activities listed below take place out-of-doors. Conventional stormwater treatment is not considered protective of groundwater in these situations. If structural separation at the site prevents discharge of stormwater from the area to the UIC facility, the prohibition is limited to the portion of the site where that activity takes place; stormwater from other portions of the site such as roofs and parking areas may be discharged to UIC facilities in accordance with Tables 5.6.1-5.6.3. If structural separation is not practicable, stormwater from the entire site must be handled on site with a closed-loop system or discharged to sanitary sewer if allowed by the local jurisdiction.

- Areas where stormwater comes into contact with surfaces subject to:
  - Vehicle maintenance, repair and servicing
  - Vehicle washing
  - Airport deicing activities
  - Storage of treated lumber
  - Storage or handling of hazardous materials;
  - Storage, transfer, treatment or disposal of hazardous wastes
  - Handling of radioactive materials

- Recycling facilities (unless limited to glass products)
- Industrial or commercial areas without management plans for proper storage and spill prevention, control, and containment appropriate to the types of materials handled at the facility (see Chapter 3 for information on stormwater pollution prevention plans and Chapter 8 for source control)
- Sites where any activities subject to the Resource Conservation and Recovery Act (RCRA) take place

See also “Land uses or activities with special treatment requirements” in sub-section 5.6.3 above.

5.6.6 Design Criteria

The UIC facility must be designed in accordance with local jurisdiction requirements or following the guidance in Sections 6.3.3 through 6.3.5. Pre-treatment facilities must be designed in accordance with the criteria established in Section 2.2.5 and in this chapter; in another manual or document approved by Ecology; or by local jurisdictions.

5.6.7 Construction Criteria

The UIC facility must be constructed in accordance with local jurisdiction requirements or following the guidance in Sections 6.3.3 through 6.3.5. Pre-treatment facilities must be constructed in accordance with the criteria established in Section 2.2.5 and in this chapter; in another manual or document approved by Ecology; or by local jurisdictions. <u>All UIC facilities must be registered with the Department of Ecology in accordance with the submittal requirements established in the UIC rule.</u> The project proponent should begin the registration process during the design phase and submit the completed paperwork prior to first use of the UIC facility.

5.6.8 Operation and Maintenance Criteria

The UIC facility must be operated and maintained in accordance with state or local jurisdiction requirements. Pre-treatment for solids removal is recommended to ensure protection of long-term infiltration capacity and reduced frequency of maintenance for any UIC facility; pre-treatment will also reduce the long-term accumulation of contaminants in the vadose zone. Pre-treatment facilities must be operated and maintained in accordance with the criteria established in this Manual, in another manual or document approved by Ecology, or by local jurisdictions. Frequent inspections and regular maintenance will improve the long-term performance of the facilities.

5.7 Wetpool/Wetpond and Dry Pond Facilities

5.7.1 Purpose and Definition

A wetpond is a constructed stormwater pond that retains a permanent pool of water ("wetpool") at least during the wet season. The volume of the wetpool is related to the effectiveness of the pond in settling particulate pollutants. As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Peak flow control can be provided in the "live storage" area above the permanent pool. Figures 5.7.1 and 5.7.2 illustrates a typical wet pond BMP.

The following design, construction, and operation and maintenance criteria cover two wetpond applications - the basic wetpond and the large wetpond. Large wetponds are designed for higher levels of pollutant removal.

BMP T5.70 Basic Wetpond

BMP T5.71 Large Wetpond

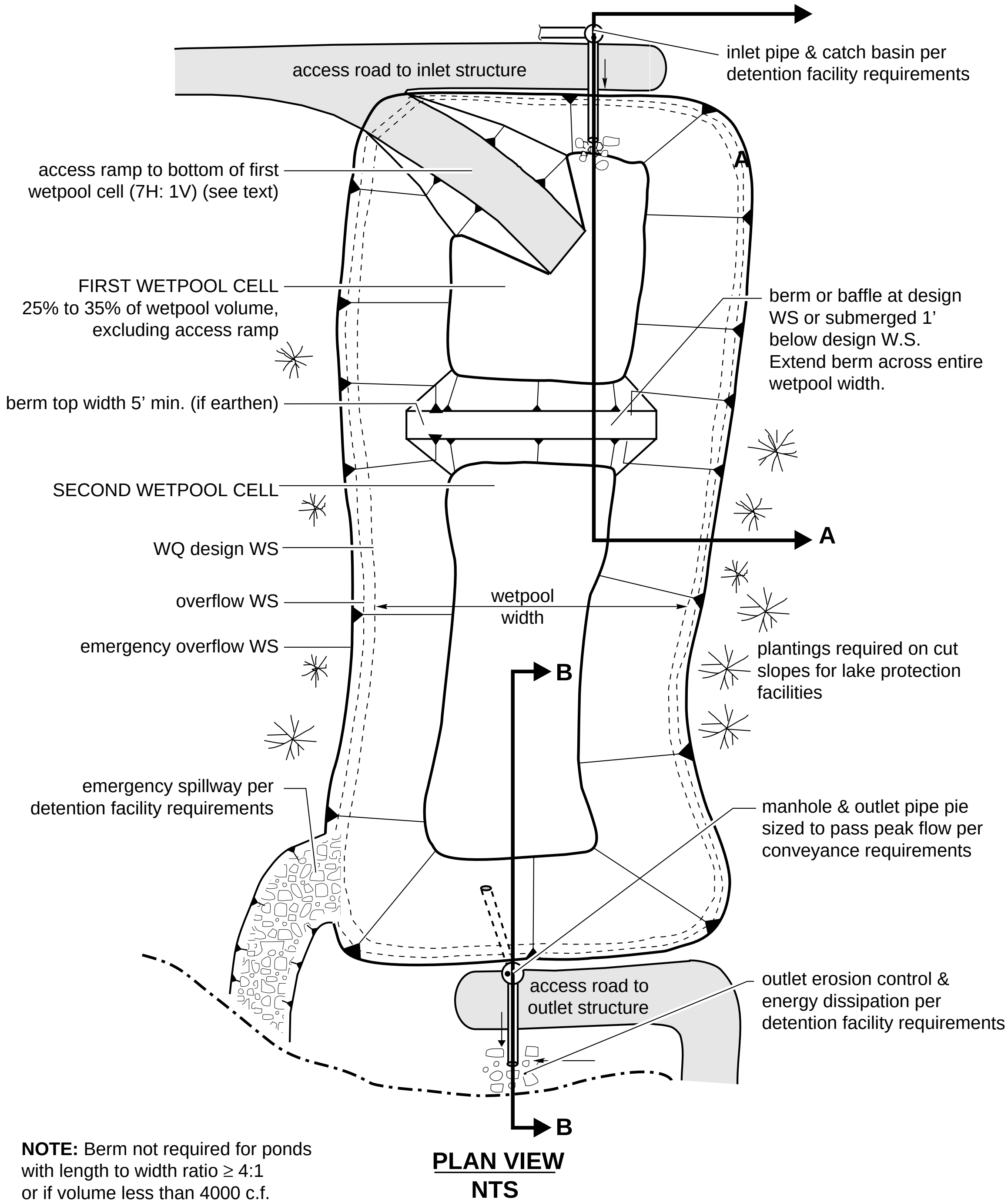
A wetpond is a constructed stormwater pond or portion of facility, that retains a pool of water (the "wetpool"). In some areas the wetpool may be permanent, at least during the wet season. The volume of the wetpond is related to the effectiveness of the pond in settling particulate pollutants. As an option, a shallow marsh area can be created within the permanent pool volume to provide additional treatment for nutrient removal. Peak flow control can be provided in the "live storage" area above the permanent pool. Figures 5.7.1 and 5.7.2 illustrate a typical wetpond BMP.

A combined detention/wetpool places a detention pond or vault on top of the wetpond or vault. The wetpond or vault is designed per this section and the detention pond or vault is designed per Section 6.2. The sediment storage area of the detention facility can be deleted.

Descriptive information about dry ponds and extended detention dry ponds is provided at the end of section 5.7.3 Design Criteria.

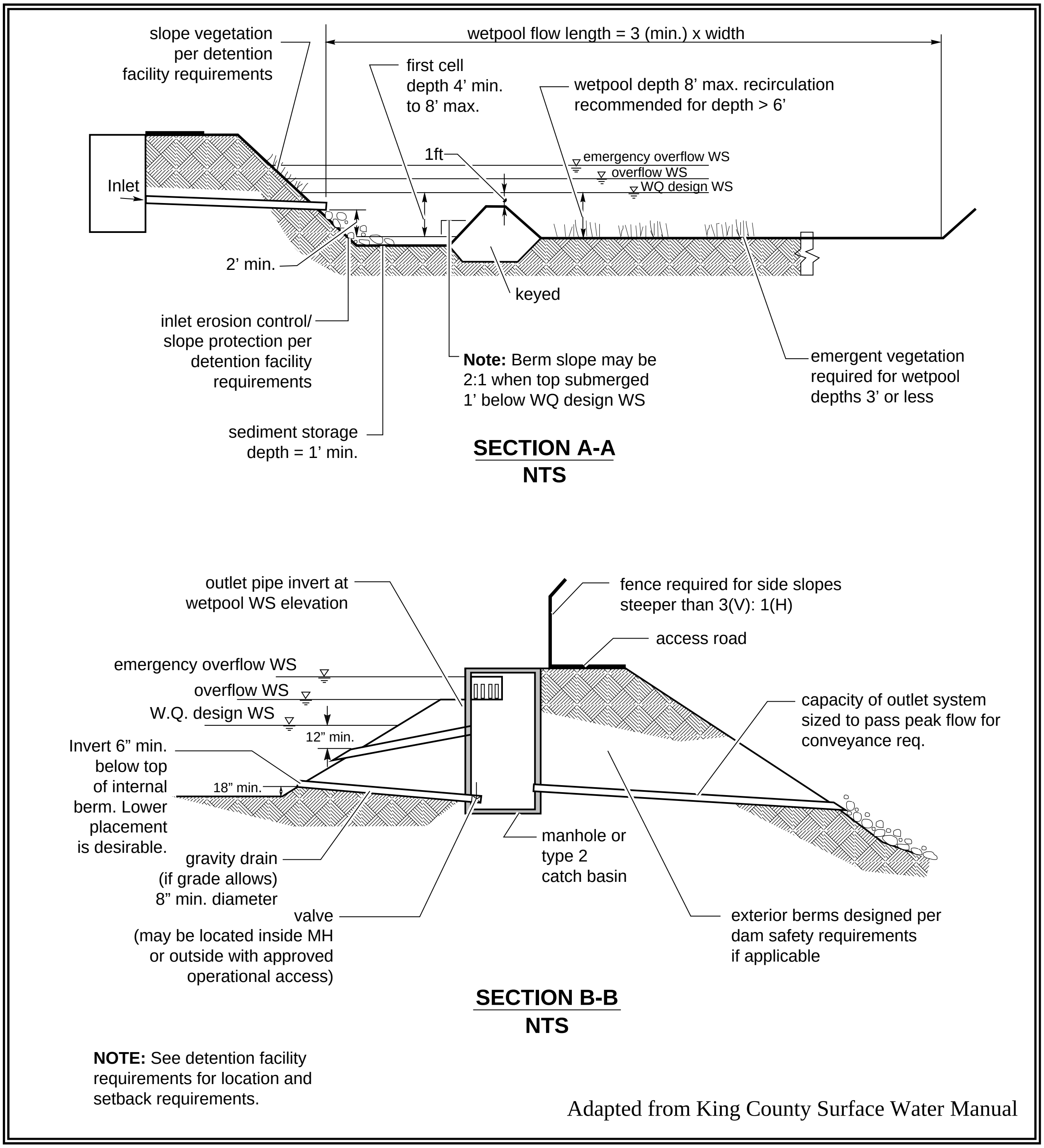
UIC regulations do not apply to these facilities (see section 5.6).

Figure 5.7.1 Wetpond/Wetpool (plan view)



Adapted from King County Surface Water Manual

Figure 5.7.2 Wetpond (sections)



5.7.2 Application and Limitations

A wetpond requires a larger area than a biofiltration swale or a sand filter, but it can be integrated to the contours of a site fairly easily. In clayey or silty soils, the wetpond may hold a permanent pool of water that provides an attractive aesthetic feature. In more porous soils, wet ponds may still be used, but water seepage from unlined cells could result in a dry pond, particularly in the summer months. Lining the first cell with a low permeability liner is one way to deal with this situation. As long as the first cell retains a permanent pool of water, this situation will not reduce the pond's effectiveness but may be an aesthetic drawback.

Wetponds may be single-purpose facilities, providing only runoff treatment, or they may be combined with a detention pond to also provide flow control. If combined, the wetpool can often be stacked under the detention pond with little further loss of development area. See Chapter 6 for the design of detention ponds.

5.7.3 Design Criteria

The primary design factor that determines a wetpond's treatment efficiency is the volume of the wetpool. The larger the wetpool volume, the greater the potential for pollutant removal. The wetpool volume provided shall be equal to or greater than the total volume of runoff from the water quality design storm.

Also important are the avoidance of short-circuiting and the promotion of plug flow. **Plug flow** describes the hypothetical condition of stormwater moving through the pond as a unit, displacing the "old" water in the pond with incoming flows. To prevent short-circuiting, water is forced to flow, to the extent practical, to all potentially available flow routes, avoiding "dead zones" and maximizing the time water stays in the pond during the active part of a storm.

Design features that encourage plug flow and avoid dead zones are:

- Dissipating energy at the inlet.
- Providing a large length-to-width ratio.
- Providing a broad surface for water exchange using a berm designed as a broad-crested weir to divide the extended detention dry pond into two cells rather than a constricted area such as a pipe.
- Maximizing the flowpath between inlet and outlet, including the vertical path, also enhances treatment by increasing residence time.

Sizing Procedure

Procedures for determining a wetpool's dimensions and volume are outlined below.

Step 1: Identify required wetpool volume using the following table or the SCS (now known as NRCS) curve number equations presented in Chapter 4 - Hydrologic Analysis and Design. For a Large Wetpond increase size of basic pond by 50%.

Table 5.7.1 Wetpond sizing table for basic treatment design

2-YEAR 24-HOUR PRECIPITATION (in)		POND VOLUME PER 1000 SQUARE-FEET OF IMPERVIOUS AREA	EXAMPLES OF APPLICABLE SITES
FROM	TO		
0.60	0.80	43.3 cubic-feet	Moses Lake
0.81	1.00	57.1 cubic-feet	Yakima, Kennewick
1.01	1.20	79.7 cubic-feet	Wenatchee, Walla Walla
1.21	1.40	97.1 cubic-feet	Colfax, Colville
1.41	and greater	Hydrologic Method Required	Eastern and Cascade Mountains

Step 2: Determine wetpool dimensions. Determine the wetpool dimensions satisfying the design criteria outlined below and illustrated in Figures 5.7.1 and 5.7.2. A simple way to check the volume of each wetpool cell is to use the following equation:

$$V = \frac{h(A_1 + A_2)}{2}$$

Where: V = wetpool volume (cu. ft.)
h = wetpool average depth (ft.)
A_1 = water quality design surface area of wetpool (sq. ft.)
A_2 = bottom area of wetpool (sq. ft.)

Step 3: Design primary overflow water surface. See Chapter 6 to determine the overflow water surface for detention ponds.

Step 4: Determine extended detention dry pond dimensions. General extended detention dry pond design criteria and concepts are shown in Figures 5.7.1 and 5.7.2.

Wetpool Geometry

The wetpool should be divided into two cells separated by a baffle or berm. The first cell should contain between 25 to 35 percent of the total wetpool volume. The baffle or berm volume shall not count as part of the total wetpool volume. The term baffle means a vertical divider placed across the entire width of the pond, stopping short of the bottom. A berm is a vertical divider typically built up from the bottom, or if in a vault, connects all the way to the bottom.

Intent: The full-length berm or baffle promotes plug flow and enhances quiescence and laminar flow through as much of the entire water volume as possible. Alternative methods to the full-length berm or baffle that provide equivalent flow characteristics may be approved on a case-by-case basis by the local jurisdiction.

Sediment storage should be provided in the first cell. The sediment storage should have a minimum depth of 1 foot. A fixed sediment depth monitor should be installed in the first cell to gauge sediment accumulation unless an alternative gauging method is proposed.

The minimum depth of the first cell should be 4 feet, exclusive of sediment storage requirements. The depth of the first cell may be greater than the depth of the second cell.

The maximum depth of each cell should not exceed 8 feet (exclusive of sediment storage in the first cell). Pool depths of 3 feet or shallower (second cell) should be planted with emergent wetland vegetation.

Inlets and outlets should be placed to maximize the flowpath through the facility. The ratio of flowpath length to width from the inlet to the outlet should be at least 3:1. The **flowpath length** is defined as the distance from the inlet to the outlet, as measured at mid-depth. The **width** at mid-depth can be found as follows: width = (average top width + average bottom width)/2.

Ponds with wetpool volumes less than or equal to 4,000 cubic feet may be single celled (i.e., no baffle or berm is required). However, it is especially important in this case that the flow path length be maximized. The ratio of flow path length to width should be at least 4:1 in single celled extended detention dry ponds, but should preferably be 5:1.

All inlets should enter the first cell. If there are multiple inlets, the length-to-width ratio should be based on the average flowpath length for all inlets. The first cell may be lined as needed.

Berms, Baffles, and Slopes

A berm or baffle should extend across the full width of the wetpool, and tie into the wetpool side slopes. If the berm embankments are greater than 4 feet in height, the berm must be constructed by excavating a key equal to 50 percent of the embankment cross-sectional height and width. This requirement may be waived if authorized by a geotechnical engineer based on specific site conditions. The geotechnical analysis should address situations in which one of the two cells is empty while the other remains full of water.

The top of the berm may extend to the water quality design water surface or be 1 foot below the water quality design water surface. If at the water quality design water surface, berm side slopes should be 3H:1V. Berm side slopes may be steeper (up to 2:1) if the berm is submerged 1 foot.

<u>Intent</u>: Submerging the berm is intended to enhance safety by discouraging pedestrian access when side slopes are steeper than 3H:1V. An alternative to the submerged berm design is the use of barrier planting to prevent easy access to the divider berm in an unfenced extended detention dry pond.

If good vegetation cover is not established on the berm, erosion control measures should be used to prevent erosion of the berm back-slope when the pond is initially filled.

The interior berm or baffle may be a retaining wall provided that the design is prepared and stamped by a licensed civil engineer. If a baffle or retaining wall is used, it should be submerged 1 foot below the design water surface to discourage access by pedestrians.

Embankments

Embankments that impound water must comply with the Washington State Dam Safety Regulations (Chapter 173-175 WAC). If the impoundment has a storage capacity (including both water and sediment storage volumes) greater than 10 acre-feet (435,600 cubic feet or 3.26 million gallons) above natural ground level, then dam safety design and review are required by the Department of Ecology.

Inlet and Outlet

See Figures 5.7.1 and 5.7.2 details on the following requirements:

The inlet to the wetpool should be submerged with the inlet pipe invert a minimum of two feet from the pond bottom (not including sediment storage). The top of the inlet pipe should be submerged at least 1 foot, if possible.

<u>Intent</u>: The inlet is submerged to dissipate energy of the incoming flow. The distance from the bottom is set to minimize re-suspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

An outlet structure shall be provided. Either a Type 2 catch basin with a grated opening (jail house window) or a manhole with a cone grate (birdcage) may be used. No sump is required in the outlet structure for extended detention dry ponds not providing detention storage. The outlet structure receives flow from the pond outlet pipe. The grate or birdcage openings provide an overflow route should the pond outlet pipe become clogged. The overflow criteria provided below specifies the sizing and position of the grate opening.

The pond outlet pipe (as opposed to the manhole or type 2 catch basin outlet pipe) should be back-sloped or have a turn-down elbow, and extend 1 foot below the WQ design water surface. Note: A floating outlet, set to draw water from 1 foot below the water surface, is also acceptable if vandalism concerns are adequately addressed.

<u>Intent</u>: The inverted outlet pipe provides for trapping of oils and floatables in the extended detention dry pond.

The pond outlet pipe shall be sized, at a minimum, to pass the WQ design flow. Note: The highest invert of the outlet pipe sets the WQ design water surface elevation.

The overflow criteria for single-purpose (treatment only, not combined with flow control) wetpools are as follows:

- The requirement for primary overflow is satisfied by either the grated inlet to the outlet structure or by a birdcage above the pond outlet structure.
- The bottom of the grate opening in the outlet structure should be set at or above the height needed to pass the WQ design flow through the pond outlet pipe. Note: The grate invert elevation sets the overflow water surface elevation.
- In on-line ponds, the grated opening should be sized to pass the 100-year design flow. The capacity of the outlet system should be sized to pass the peak flow for the conveyance requirements.
- An emergency spillway shall be provided and designed according to the requirements for detention ponds (see Chapter 6 – Flow Control Facility Design).
- A gravity drain for maintenance is recommended if grade allows.

Intent: It is anticipated that sediment removal will be needed only for the first cell in the majority of cases. The gravity drain is intended to allow water from the first cell to be drained to the second cell when the first cell is pumped dry for cleaning.

All metal parts should be corrosion-resistant. Galvanized materials should not be used unless unavoidable.

Intent: Galvanized metal contributes zinc to stormwater, sometimes in very high concentrations.

Access and Setbacks

All facilities shall be a minimum of 20 feet from any structure, property line, and any vegetated buffer required by the local government, and 100 feet from any septic tank/drainfield.

All facilities shall be located away from any steep (greater than 15 percent) slope. The minimum setback from such a slope is greater than or equal to the height of the slope, unless the design professional can justify a lesser setback based on a comprehensive site evaluation. A geotechnical report must address the potential impact of a wetpond on a steep slope.

Access and maintenance roads shall be provided and designed according to the requirements for detention ponds. Access and maintenance roads shall extend to both the extended detention dry pond inlet and outlet structures. An access ramp (5H minimum:1V) shall be provided to the bottom of the first cell unless all portions of the cell can be reached and sediment loaded from the top of the pond.

If the dividing berm is also used for access, it should be built to sustain loads of up to 80,000 pounds.

Planting Requirements

If desired, the pond may be planted with dryland grasses. Sod or wetland plants should be avoided unless irrigation will be provided during the dry months.

Recommended Design Features

The following design features should be incorporated into the extended detention dry pond design where site conditions allow:

The method of construction of soil/landscape systems can cause natural selection of specific plant species. Consult a soil restoration or wetland soil scientist for site-specific recommendations. The soil formulation will impact the plant species that will flourish or suffer on the site, and the formulation should be such that it encourages desired species and discourages undesired species.

For permanent wetpool depths in excess of 6 feet, it is recommended that some form of recirculation be provided in the summer, such as a fountain or aerator, to prevent stagnation and low dissolved oxygen conditions.

A flow length-to-width ratio greater than the 3:1 minimum is desirable. If the ratio is 4:1 or greater, then the dividing berm is not required, and the pond may consist of one cell rather than two.

A tear-drop shape, with the inlet at the narrow end, rather than a rectangular pond is preferred since it minimizes dead zones caused by corners.

A small amount of base flow is desirable to maintain circulation and reduce the potential for low oxygen conditions during late summer.

Columnar deciduous trees along the west and south sides of ponds are recommended to reduce thermal heating, except that no trees or shrubs may be planted on berms meeting the criteria of dams regulated for safety. In addition to shade, trees and shrubs also discourage waterfowl use and the attendant phosphorus enrichment problems they cause. Trees should be set back so that the branches will not extend over the pond.

<u>Intent</u>: Evergreen trees or shrubs are preferred to avoid problems associated with leaf drop, except on the south and west sides which may inhibit the melting of ice during the winter. Columnar deciduous trees (e.g., hornbeam, Lombardy poplar) typically have fewer leaves than other deciduous trees.

The number of inlets to the facility should be limited; ideally there should be only one inlet. The flowpath length should be maximized from inlet to outlet for all inlets to the facility.

The access and maintenance road could be extended along the full length of the extended detention dry pond and could double as playcourts or picnic areas. Placing finely ground bark or other natural material over the road surface would render it more pedestrian friendly.

The following design features should be incorporated to enhance aesthetics where possible:

- Provide side slopes that are sufficiently gentle to avoid the need for fencing (3:1 or flatter).
- Include fountains or integrated waterfall features for privately maintained facilities.
- Provide visual enhancement with clusters of trees and shrubs. On most pond sites, it is important to amend the soil before planting since ponds are typically placed well below the native soil horizon in very poor soils. Make sure dam safety restrictions against planting do not apply.
- Orient the pond length along the direction of prevailing summer winds (typically west or southwest) to enhance wind mixing.

Extended Detention Dry Ponds

The section below lacks design criteria. All proposed designs will need evaluation and approval prior to implementation.

<u>Design Features and Considerations:</u> Dry ponds are structures that completely drain between runoff events. A perforated riser or outlet control device enables water to slowly drain from the pond. Initial attempts at stormwater management involved ponds that were designed primarily for hydraulic control. Consequently, dry ponds are some of the most widely used facilities in urban stormwater infrastructure. With the emergence of water quality issues, the desire to designate these facilities as dual-purpose detention facilities is considerable. However, standard dry ponds are generally not very effective at treating water quality. One difference is that flood damage occurs as the result runoff from events having return periods greater than two years whereas environmental damage may be caused by the cumulative effects of numerous small storms. For basins with detention times less than 12 hours, no more than 10 percent of the pollutants are captured (ASCE, 1992). Some studies have even produced negative results because of potential flushing of pollutants captured in previous small events (Pope and Hess, 1989). A bypass should be provided for large events.

<u>Intent</u>: As a way to improve water quality performance, designers have suggested that dry ponds be designed to retain stormwater for at least 24 hours. Ponds with detention times greater than 24 hours are referred to as Extended Detention dry ponds. Schueler and Helfrich (1989) recommended that sufficient volume should exist to hold the runoff

generated by 0.5 inches of effective rainfall. Because pollutant removal is by adsorption and settling, cold weather considerations regarding the changes in viscosity, and subsequently the settling velocity of particles, should be factored into the final design.

5.7.4 Construction Criteria

Sediment that has accumulated in the pond must be removed after construction in the drainage area of the pond is complete (unless used for a liner - see below).

Sediment that has accumulated in the pond at the end of construction may be used as a liner in excessively drained soils if the sediment meets the criteria for a low permeability liner and is approved for use as such by a geotechnical engineer. Sediment used for a soil liner must be graded to provide uniform coverage and thickness.

5.7.5 Operation and Maintenance

Maintenance is of primary importance if wetpools are to continue to function as originally designed. A local government, a designated group such as a homeowners' association, or a property owner should accept the responsibility for maintaining the structures and the impoundment area. A specific maintenance plan should be formulated outlining the schedule and scope of maintenance operations.

The pond should be inspected by the local government annually. The maintenance standards contained in Appendix 5A are measures for determining if maintenance actions are required as identified through the annual inspection.

Site vegetation should be trimmed as necessary to keep the pond free of leaves and to maintain the aesthetic appearance of the site. Slope areas that have become bare should be revegetated and eroded areas should be regraded prior to being revegetated.

Sediment should be removed when the 1-foot sediment zone is full plus 6 inches. Sediments should be tested for toxicants in compliance with current disposal requirements. Sediments must be disposed in accordance with current local health department requirements and the Minimum Functional Standards for Solid Waste Handling.

Any standing water removed during the maintenance operation must be properly disposed of. The preferred disposal option is discharge to a sanitary sewer at an approved location. Other disposal options include discharge back into the wetpool facility or the storm sewer system, if approved by the operator of the storm sewer system.

5.7.6 Wetvaults

BMP T5.72 Wetvaults

Purpose and Definition

A wetvault is an underground structure similar in appearance to a detention vault, except that a wetvault has a permanent pool of water (wetpool) which dissipates energy and improves the settling of particulate pollutants (see the wetvault details in Figure 5.7.3). Being underground, the wetvault lacks the biological pollutant removal mechanisms, such as algae uptake, present in surface extended detention dry ponds.

UIC regulations do not apply to these facilities if the outlet structure discharges exclusively to a conveyance system and(or) to surface water. However, UIC regulations do apply to these facilities if the outlet structure discharges into the ground, and then – provided that the design, operation, and maintenance criteria in this section are met – only the registration requirement would apply. See section 5.6.

Applications and Limitations

A wetvault may be used for commercial, industrial, or roadway projects if there are space limitations precluding the use of other treatment BMPs. The use of wetvaults for residential development is highly discouraged. Combined detention and wetvaults are allowed.

A wetvault is believed to be ineffective in removing dissolved pollutants such as soluble phosphorus or metals such as copper. There is also concern that oxygen levels will decline, especially in warm summer months, because of limited contact with air and wind. However, the extent to which this potential problem occurs has not been documented.

Below-ground structures like wetvaults are relatively difficult and expensive to maintain. The need for maintenance is often not seen and as a result routine maintenance does not occur.

If oil control is required for a project, a wetvault may be combined with an API oil/water separator.

Design Criteria

Sizing Procedure: As with wet ponds, the primary design factor that determines the removal efficiency of a wetvault is the volume of the wetpool. The larger the volume, the higher the potential for pollutant removal. Performance is also improved by avoiding dead zones (like corners) where little exchange occurs, using large length-to-width ratios, dissipating energy at the inlet, and ensuring that flow rates are uniform to the extent possible and not increased between cells.

The sizing procedure for a wetvault is identical to the sizing procedure for an extended detention dry pond. The wetpool volume for the wetvault shall be equal to or greater than the total volume of runoff from the 6-month,24-hour storm event.

Typical design details and concepts for the wetvault are shown in Figure 5.7.3.

Wetpool Geometry: Same as specified for wet ponds (see BMP T5.70 and BMP T5.71) except for the following two modifications:

The sediment storage in the first cell shall be an average of 1 foot. Because of the v-shaped bottom, the depth of sediment storage needed above the bottom of the side wall is roughly proportional to vault width according to the schedule below:

Vault Width	Sediment Depth (from bottom of side wall)
15'	10"
20'	9"
40'	6"
60'	4"

The second cell shall be a minimum of 3 feet deep since planting cannot be used to prevent re-suspension of sediment in shallow water as it can in open ponds.

Vault Structure The vault shall be separated into two cells by a wall or a removable baffle. If a wall is used, a 5-foot by 10-foot removable maintenance access must be provided for both cells. If a removable baffle is used, the following criteria apply:

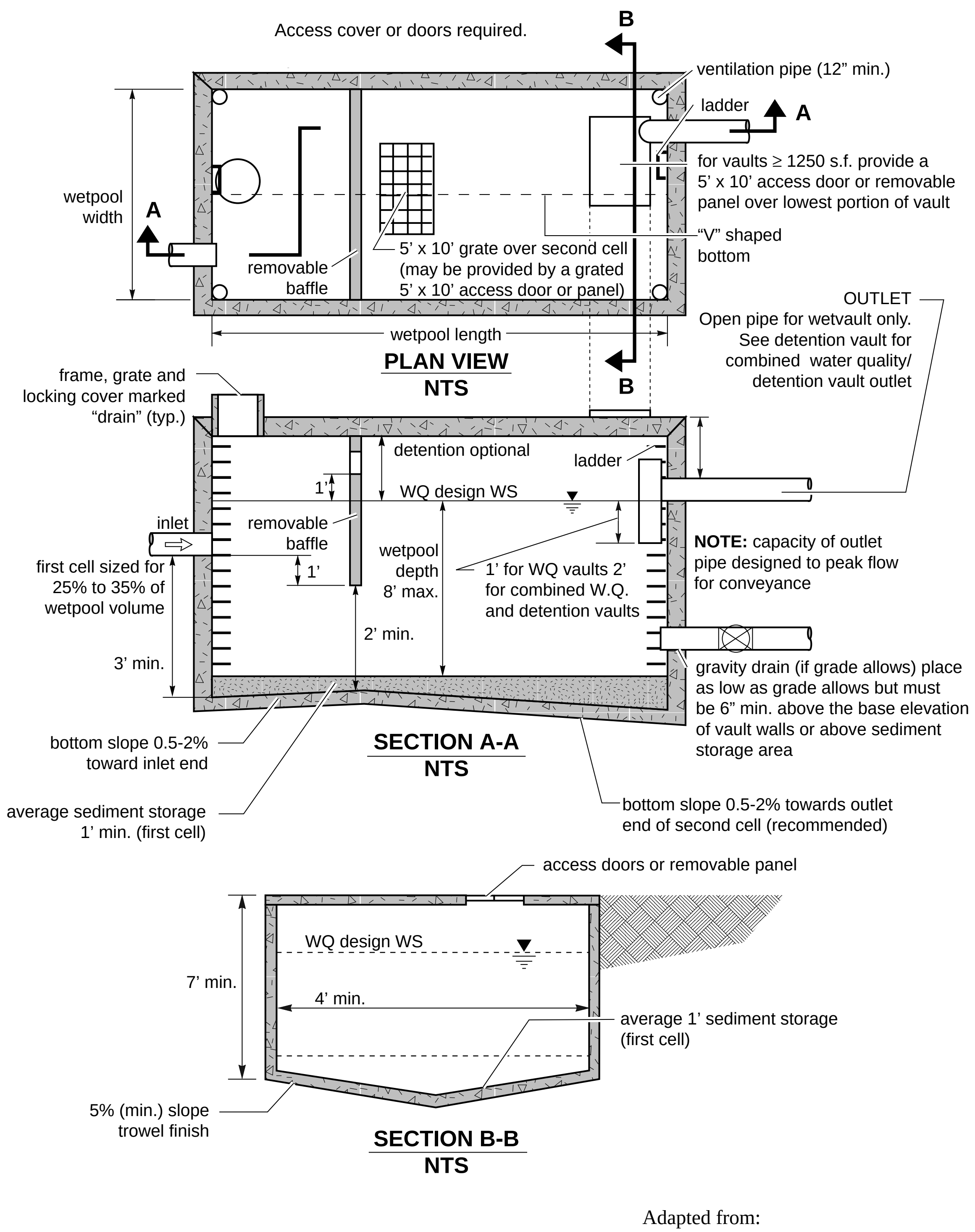
The baffle shall extend from a minimum of 1 foot above the water quality design water surface to a minimum of 1 foot below the invert elevation of the inlet pipe.

The lowest point of the baffle shall be a minimum of 2 feet from the bottom of the vault, and greater if feasible.

If the vault is less than 2,000 cubic feet (inside dimensions), or if the length-to-width ratio of the vault pool is 5:1 or greater, the baffle or wall may be omitted and the vault may be one-celled.

The two cells of a wetvault should not be divided into additional sub-cells by internal walls. If internal structural support is needed, it is preferred that post and pier construction be used to support the vault lid rather than walls. Any walls used within cells must be positioned so as to lengthen, rather than divide, the flowpath.

Figure 5.7.3 Wetvault



Adapted from:
King County Surface Water Manual

Intent: Treatment effectiveness in wetpool facilities is related to the extent to which plug flow is achieved and short-circuiting and dead zones are avoided. Structural walls placed within the cells can interfere with plug flow and create significant dead zones, reducing treatment effectiveness.

The bottom of the first cell shall be sloped toward the access opening. Slope should be between 0.5 percent (minimum) and 2 percent (maximum). The second cell may be level (longitudinally) sloped toward the outlet, with a high point between the first and second cells. The intent of sloping the bottom is to direct the sediment accumulation to the closest access point for maintenance purposes. Sloping the second cell towards the access opening for the first cell is also acceptable.

The vault bottom shall slope laterally a minimum of 5 percent from each side towards the center, forming a broad "v" to facilitate sediment removal. Note: More than one "v" may be used to minimize vault depth.

Exception: The local jurisdiction may allow the vault bottom to be flat if removable panels are provided over the entire vault. Removable panels should be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.

The highest point of a vault bottom must be at least 6 inches below the outlet elevation to provide for sediment storage over the entire bottom.

Provision for passage of flows should the outlet plug shall be provided.

Wetvaults may be constructed using arch culvert sections provided the top area at the WQ design water surface is, at a minimum, equal to that of a vault with vertical walls designed with an average depth of 6 feet.

Intent: To prevent decreasing the surface area available for oxygen exchange.

Wetvaults shall conform to the "Materials" and "Structural Stability" criteria specified for detention vaults in Chapter 6.

Where pipes enter and leave the vault below the WQ design water surface, they shall be sealed using a non-porous, non-shrinking grout.

Inlet and Outlet The inlet to the wetvault shall be submerged with the inlet pipe invert a minimum of 3 feet from the vault bottom. The top of the inlet pipe should be submerged at least 1 foot, if possible.

Intent: The submerged inlet is to dissipate energy of the incoming flow. The distance from the bottom is to minimize re-suspension of settled sediments. Alternative inlet designs that accomplish these objectives are acceptable.

Unless designed as an off-line facility, the capacity of the outlet pipe and available head above the outlet pipe should be designed to convey the 100-year design flow for developed site conditions without overtopping the vault. The available head above the outlet pipe must be a minimum of 6 inches.

The outlet pipe shall be back-sloped or have tee section, the lower arm of which should extend 1 foot below the WQ design water surface to provide for trapping of oils and floatables in the vault.

The local jurisdiction may require a bypass/shutoff valve to enable the vault to be taken offline for maintenance.

Access Requirements Same as for detention vaults (see Chapter 6) except for the following additional requirement for wetvaults:

A minimum of 50 square feet of grate should be provided over the second cell. For vaults in which the surface area of the second cell is greater than 1,250 square feet, 4 percent of the top should be grated. This requirement may be met by one grate or by many smaller grates distributed over the second cell area. Note: a grated access door can be used to meet this requirement.

<u>Intent</u>: The grate allows air contact with the wetpool in order to minimize stagnant conditions which can result in oxygen depletion, especially in warm weather.

Access Roads, Right of Way, and Setbacks Same as for detention vaults (Chapter 6).

Recommended Design Features

The following design features should be incorporated into wetvaults where feasible, but they are not specifically required:

- The floor of the second cell should slope toward the outlet for ease of cleaning.
- The inlet and outlet should be at opposing corners of the vault to increase the flowpath.
- A flow length-to-width ratio greater than 3:1 minimum is desirable.
- Lockable grates instead of solid manhole covers are recommended to increase air contact with the wetpool.
- Galvanized materials shall not be used unless unavoidable.
- The number of inlets to the wetvault should be limited, and the flowpath length should be maximized from inlet to outlet for all inlets to the vault.

Construction Criteria

Sediment that has accumulated in the vault must be removed after construction in the drainage area is complete. If no more than 12 inches of sediment have accumulated after the infrastructure is built, cleaning may be left until after building construction is complete. In general, sediment accumulation from stabilized drainage areas is not expected to exceed an average of 4 inches per year in the first cell. If sediment accumulation is greater than this amount, it will be assumed to be from construction unless it can be shown otherwise.

Operation and Maintenance

Accumulated sediment and stagnant conditions may cause noxious gases to form and accumulate in the vault. Vault maintenance procedures must meet OSHA confined space entry requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Facilities should be inspected by the local government annually. The maintenance standards contained in Appendix 5A of this chapter are measures for determining if maintenance actions are required as identified through the annual inspection.

Sediment should be removed when the 1-foot sediment zone is full plus 6 inches. Sediments should be tested for toxicants in compliance with current disposal requirements. Sediments must be disposed in accordance with current local health department requirements.

Any standing water removed during the maintenance operation must be properly disposed of. The preferred disposal option is discharge to a sanitary sewer at an approved location.

See Appendix 5A for more detailed information.

Modifications for Combining with a Baffle Oil/Water Separator

If the project site is a high-use site and a wetvault is proposed, the vault may be combined with a baffle oil/water separator to meet the runoff treatment requirements with one facility rather than two. Structural modifications and added design criteria are given below. However, the maintenance requirements for baffle oil/water separators must be adhered to, in addition to those for a wetvault. This will result in more frequent inspection and cleaning than for a wetvault used only for TSS removal. See Appendix 5A for information on maintenance of baffle oil/water separators.

1. The sizing procedures for the baffle oil/water separator (Section 5.10) should be run as a check to ensure the vault is large enough. If the oil/water separator sizing procedures result in a larger vault size, increase the wetvault size to match.
2. An oil retaining baffle shall be provided in the second cell near the vault outlet. The baffle should not contain a high-flow overflow, or else the retained oil will be washed out of the vault during large storms.
3. The vault shall have a minimum length-to-width ratio of 5:1.

4. The vault shall have a design water depth-to-width ratio of between 1:3 to 1:2.

5. The vault shall be watertight and shall be coated to protect from corrosion.

6. Separator vaults shall have a shutoff mechanism on the outlet pipe to prevent oil discharges during maintenance and to provide emergency shut-off capability in case of a spill. A valve box and riser shall also be provided.

7. Wetvaults used as oil/water separators must be off-line and must bypass flows greater than the WQ design flow.

Intent: This design minimizes the entrainment and/or emulsification of previously captured oil during very high flow events.

5.7.7 Stormwater Treatment Wetlands

BMP T5.73 Stormwater Treatment Wetlands

Purpose and Definition

In land development situations, wetlands are usually constructed for two main reasons: to replace or mitigate impacts when natural wetlands are filled or impacted by development (mitigation wetlands), and to treat stormwater runoff (stormwater treatment wetlands). Stormwater treatment wetlands are shallow man-made ponds that are designed to treat stormwater through the biological processes associated with emergent aquatic plants (see the stormwater wetland details in Figure 5.7.4 and Figure 5.7.5).

Wetlands created to mitigate disturbance impacts, such as filling, may not also be used as stormwater treatment facilities. This is because of the different, incompatible functions of the two kinds of wetlands. Mitigation wetlands are intended to function as full replacement habitat for fish and wildlife, providing the same functions and harboring the same species diversity and biotic richness as the wetlands they replace. Stormwater treatment wetlands are used to capture and transform pollutants, just as wetponds are, and over time pollutants will concentrate in the sediment. This is not a healthy environment for aquatic life. Stormwater treatment wetlands are used to capture pollutants in a managed environment so that they will not reach natural wetlands and other ecologically important habitats. In addition, vegetation must occasionally be harvested and sediment dredged in stormwater treatment wetlands, further interfering with use for wildlife habitat.

In general, stormwater wetlands perform well to remove sediment, metals, and pollutants that bind to humic or organic acids. Phosphorus removal in stormwater wetlands is highly variable.

UIC regulations do not apply to these facilities (see section 5.6).

Applications and Limitations

This stormwater wetland design occupies about the same surface area as wetponds, but has the potential to be better integrated aesthetically into a site because of the abundance of emergent aquatic vegetation. The most critical factor for a successful design is the provision of an adequate supply of water for most of the year. Careful planning is needed to be sure sufficient water will be retained to sustain good wetland plant growth. A source of irrigation water may be needed. Since water depths are shallower than in wetponds, water loss by evaporation is an important concern. Stormwater wetlands are a good WQ facility choice in areas with high winter groundwater levels.

Design Criteria

When used for stormwater treatment, stormwater wetlands employ some of the same design features as wetponds. However, instead of gravity settling being the dominant treatment process, pollutant removal mediated by aquatic vegetation and the microbiological community associated with that vegetation becomes the dominant treatment process. Thus when designing wetlands, water volume is not the dominant design criteria. Rather, factors which affect plant vigor and biomass are the primary concerns.

Wetland Geometry Criteria

1. Stormwater wetlands shall consist of two cells, a pre-settling cell and a wetland cell.

2. The pre-settling cell shall contain approximately 33 percent of the wetpool volume.

    - There is currently no single accepted method for computing volume requirements for constructed wetlands. The procedure may be left to local practice. The volume needs to include a slowly draining portion as well as a permanent pool. The slowly draining pool should release the design runoff volume over a period of at least 5 days. No more than half the volume should be released within about 2.5 days.

    - The general rule of thumb for the permanent pool is that it should provide a residence time of at least 14 days. It is not drained through an outlet but rather through evapotranspiration and infiltration. However, this is inadequate for eastern Washington due to the precipitation patterns during our summers and cold winters: a dry wetland with dead vegetation does not provide much protection during fall precipitation events, and a near-frozen pond does not promote much biological uptake of nutrients during early spring events.

- See Koob et al (1999) for a statistical procedure for analyzing the time between precipitation events versus the risk of a dry pond. Local infiltration data and evapotranspiration data are essential to produce reliable estimates.

3. The depth of the pre-settling cell shall be between 4 feet (minimum) and 8 feet (maximum), excluding sediment storage.

4. One foot of sediment storage shall be provided in the pre-settling cell.

5. The permanent pool in the wetland cell shall have an average water depth of about 1.5 feet (plus or minus 3 inches). The average water depth required for the total storage volume is typically 3 feet.

6. The “berm” separating the two cells shall be shaped such that its downstream side gradually slopes to form the second shallow wetland cell (see the section view in Figure 5.7.4). Alternatively, the second cell may be graded naturalistically from the top of the dividing berm (see Criterion 8 below).

7. The top of berm shall be either at the water quality design water surface or submerged 1 foot below the water quality design water surface, as with wetponds. Correspondingly, the side slopes of the berm must meet the following criteria:

   a. If the top of berm is at the water quality design water surface, the berm side slopes shall be no steeper than 3H:1V.

   b. If the top of berm is submerged 1 foot, the upstream side slope may be up to 2H:1V. If the berm is at the water surface, then for safety reasons, its slope should not be greater than 3:1, just as the pond banks should not be greater than 3:1 if the pond is not fenced. A steeper slope (2:1 rather than 3:1) is allowable if the berm is submerged in 1 foot of water. If submerged, the berm is not considered accessible, and the steeper slope is allowable.

8. Two examples are provided for grading the bottom of the wetland cell. One example is a shallow, evenly graded slope from the upstream to the downstream edge of the wetland cell (see Figure 5.7.4). The second example is a "naturalistic" alternative, with the specified range of depths intermixed throughout the second cell (see Figure 5.7.5). A distribution of depths shall be provided in the wetland cell depending on whether the dividing berm is at the water surface or submerged (see Table 5.7.2 below). The maximum depth is 2.5 feet in either configuration. Other configurations within the wetland geometry constraints listed above may be approved by the local jurisdiction.

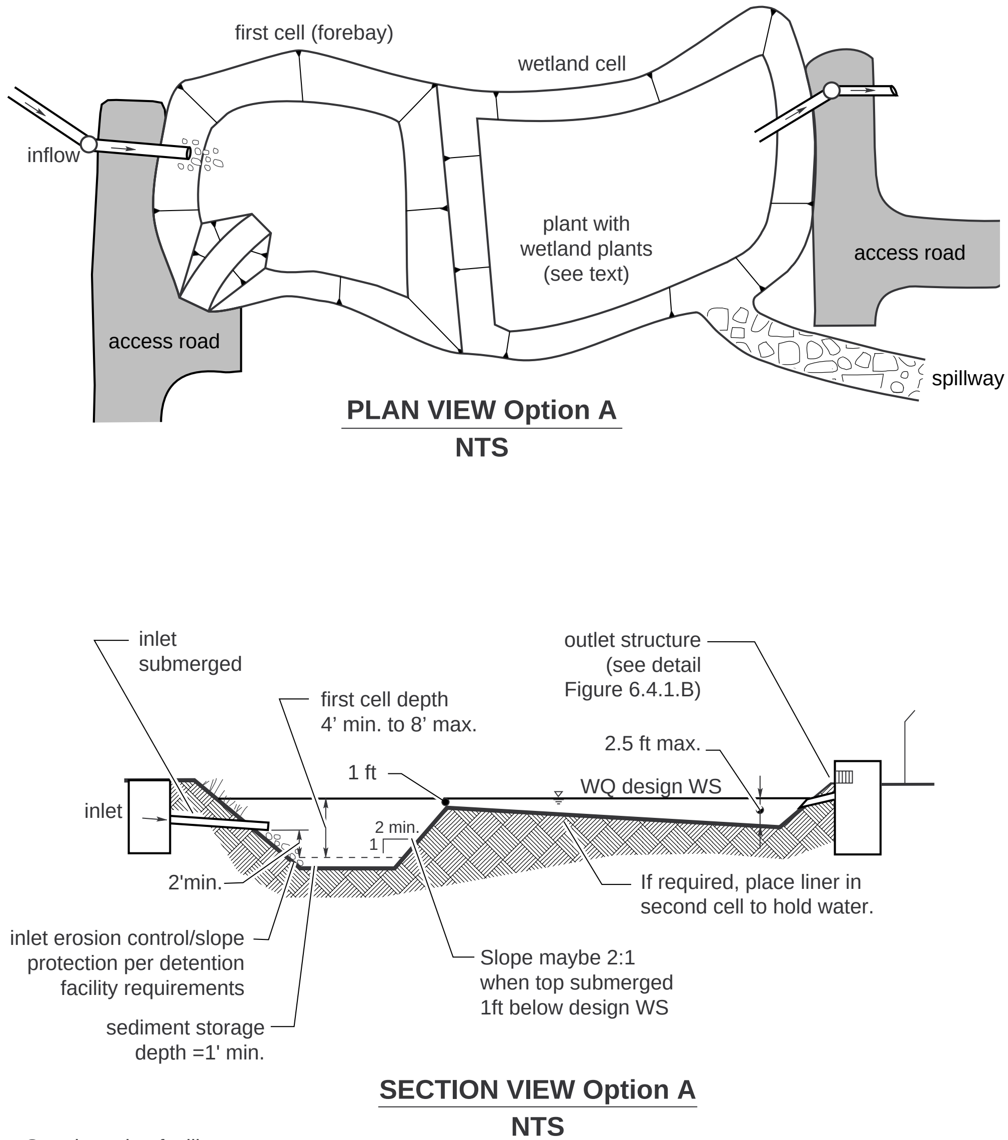
9. A minimum length-to-width ratio of 2:1 is recommended. The shape is generally dictated by the surrounding site geometry, but the purpose of this recommendation is to prevent short-circuiting of water across the pond. Baffles, islands, and creative inlet structures can be used to promote adequate mixing in challenging settings.

10. It is intended that the intent of the Wetland Geometry Criteria listed above generally be met. Appropriate deviations may be necessary, based upon site specific considerations.

Table 5.7.2 – Distribution of depths in wetland cell

Dividing Berm at WQ Design Water Surface		Dividing Berm Submerged 1-Foot	
Depth Range (feet)	**Percent**	**Depth Range (feet)**	**Percent**
0.1 to 1	25	1 to 1.5	40
1 to 2	55	1.5 to 2	40
2 to 2.5	20	2 to 2.5	20

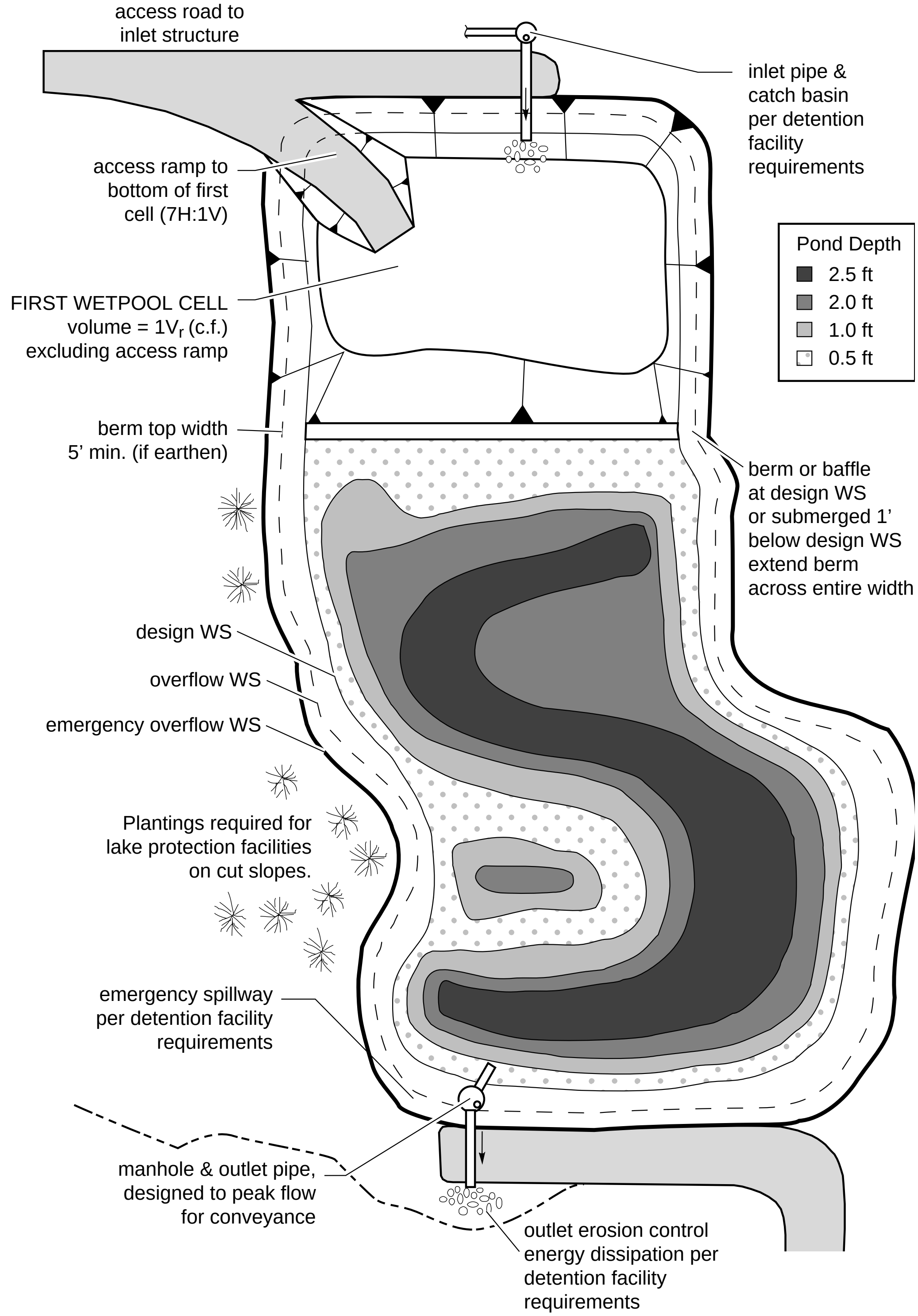
Figure 5.7.4 Stormwater Treatment Wetland — Option A



Note: See detention facility requirements for location and setback requirements.

Adapted from King County Surface Water Design Manual

Figure 5.7.5   Stormwater Treatment Wetland — Option B



PLAN VIEW Option B

NTS

Adapted from King County Surface Water Design Manual

Sizing Procedure

Step 1: The volume of a basic wetpond is used as a template for sizing the stormwater wetland. See Section 5.7.3 for sizing procedure.

Step 2: Calculate the surface area of the stormwater wetland. The surface area of the wetland shall be the same as the top area of a wetpond sized for the same site conditions. Calculate the surface area of the stormwater wetland by using the volume from Step 1 and dividing by the average water depth (typically 3 feet).

Step 3: Determine the surface area of the first cell of the stormwater wetland. Use the volume determined from Criterion 2 under "Wetland Geometry", and the actual depth of the first cell.

Step 4: Determine the surface area of the wetland cell. Subtract the surface area of the first cell (Step 3) from the total surface area (Step 2).

Step 5: Determine water depth distribution in the second cell. Decide if the top of the dividing berm will be at the surface or submerged (designer's choice). Adjust the distribution of water depths in the second cell according to Criterion 8 under "Wetland Geometry" (below). Note: This will result in a facility that holds less volume than that determined in Step 1 above. This is acceptable.

Intent: The surface area of the stormwater wetland is set to be roughly equivalent to that of a wetpond designed for the same site so as not to discourage use of this option.

Step 6: Choose plants. See Table 5.7.3 for a list of plants recommended for wetpond water depth zones, or consult a wetland scientist.

Table 5.7.3 -- Emergent wetland plant species recommended for wetponds, eastern Washington arid and cold climates

Species	Common Name	Notes	Maximum Depth
INUNDATION TO 1 FOOT			
Deschampsia caespitosa	Tufted hairgrass	Prairie to coast	to 2 feet
Carex nebrascensis	Nebraska sedge	Wet meadows to pond margins	
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	to 2 feet
Glyceria occidentalis	Western mannagrass	Marshes, pond margins	to 2 feet
Juncus articulatus	Jointed rush	Wet soils, wetland margins	
Smilacina stellata	False Solomon's seal	Moist areas; needs saturated soils all summer	
Scirpus validus(2)	Soft-stem bulrush	Wet ground to shallow water	
Scirpus microcarpus(2)	Small-fruited bulrush	Wet ground to 18 inches depth	18 inches
Sagittaria latifolia(2)	Arrowhead	Margins of ponds, shallow water	
INUNDATION 1 TO 2 FEET			
Agrostis idahoensis	Idaho bent grass	Prairie, wet meadows	Does not withstand flooding-moist soil
Alisma plantago-aquatica	American water plantain	Shallow to deep marshes	
Eleocharis palustris	Spike rush	Margins of ponds, wet meadows	Best in 1' zone
Calamagrostis canadensis	Bluejoint reedgrass	Marshes, pond margins	
Juncus ensifolius	Dagger-leaf rush	Wet meadows, pastures, wetland margins	
Scirpus validus(2)	Soft-stem bulrush	Wet ground to 18 inches depth	18 inches
Sparganium eurycarpum	Broad-fruited burreed	Shallow standing water, saturated soils	
INUNDATION 1 TO 3 FEET			
Carex nebrascensis	Nebraska sedge	Wet meadows to pond margins	1.5 to 3 feet
Beckmania syzigachne(1)	American sloughgrass	Wet meadows to pond margins	
Scirpus acutus(2)	Hardstem bulrush	Single tall stems, not clumping	to 3 feet
Scirpus americanus(2)	Three-square bulrush		
INUNDATION GREATER THAN 3 FEET			
Nuphar polysepalum	Yellow water-lily	Deep water	3 to 7.5 feet
Potamogeton natans	Floating-leaf pondweed	Shallow to deep ponds	to 6 feet

Notes:

(1) Non-native species. However *Beckmania syzigachne* is native to Oregon.

(2) *Scirpus* tubers must be protected from foraging waterfowl until established. Emerging aerial stems should project above water surface to allow oxygen transport to the roots.

Primary sources: Washington State Department of Ecology, *Restoring Wetlands in Washington*, Pub. #93-17. Hortus Northwest, *Wetland Plants for Western Oregon*, Issue 4, 1993. Hitchcock and Cronquist, *Flora of the Pacific Northwest*, 1973.

Lining Requirements

In infiltrative soils, both cells of the stormwater wetland shall be lined. To determine whether a low-permeability liner or a treatment liner is required, determine whether the following conditions will be met. If soil permeability will allow sufficient water retention, lining may be waived.

1 The second cell must retain water for at least 10 months of the year.
2. The first cell must retain at least three feet of water year-round.
3. A complete precipitation record shall be used when establishing these conditions. Evapotranspiration losses shall be taken into account as well as infiltration losses.

<u>Intent:</u> Many wetland plants can adapt to periods of summer drought, so a limited drought period is allowed in the second cell. This may allow a treatment liner rather than a low permeability liner to be used for the second cell. The first cell must retain water year-round in order for the presettling function to be effective.

- If a low permeability liner is used, a minimum of 18 inches of native soil amended with good topsoil or compost (one part compost mixed with 3 parts native soil) must be placed over the liner. For geomembrane liners, a soil depth of 3 feet is recommended to prevent damage to the liner during planting. Hydric soils are not required.

The criteria for liners given in Section 5.8.5 must be observed.

Inlet and Outlet

Same as for wetponds (see BMP T5.70 and BMP T5.71).

Access and Setbacks

- Location of the stormwater wetland relative to site constraints (e.g., buildings, property lines) shall be the same as for detention ponds (see Chapter 6). See Section 5.3.3 for typical setback requirements for WQ facilities.
- Access and maintenance roads shall be provided and designed according to the requirements for detention ponds (see Chapter 6). Access and maintenance roads shall extend to both the wetland inlet and outlet structures. An access ramp (7H minimum:1V) shall be provided to the bottom of the first cell unless all portions of the cell can be reached and sediment loaded from the top of the wetland side slopes.
- If the dividing berm is also used for access, it should be built to sustain loads of up to 80,000 pounds.

Planting Requirements

The wetland cell shall be planted with emergent wetland plants following the recommendations given in Table 5.7.2 or the recommendations of a wetland specialist. Note: Cattails (Typha latifolia) are not recommended. They tend to escape to natural wetlands and crowd out other species. In addition, the shoots die back each fall and will result in oxygen depletion in the wetpool unless they are removed.

Construction Criteria

- Construction and maintenance considerations are the same as for wetponds.
- Construction of the naturalistic alternative (Option B) can be easily done by first excavating the entire area to the 1.5-foot average depth. Then soil subsequently excavated to form deeper areas can be deposited to raise other areas until the distribution of depths indicated in the design is achieved.

Operation and Maintenance

- Wetlands should be inspected at least twice per year during the first three years during both growing and non-growing seasons to observe plant species presence, abundance, and condition; bottom contours and water depths relative to plans; and sediment, outlet, and buffer conditions.
- Maintenance should be scheduled around sensitive wildlife and vegetation seasons.
- Plants may require watering, physical support, mulching, weed removal, or replanting during the first three years.
- Nuisance plant species should be removed and desirable species should be replanted.
- The effectiveness of harvesting for nutrient control is not well documented. There are many drawbacks to harvesting, including possible damage to the wetlands and the inability to remove nutrients in the below-ground biomass. If harvesting is practiced, it should be done in the late summer.

5.8 Sand Filtration Treatment Facilities

BMP T5.80 Basic Sand Filter

BMP T5.81 Large Sand Filter

5.8.1 Description

A typical sand filtration system consists of a pretreatment system, flow spreader(s), a sand bed, and the underdrain piping. The sand filter bed includes a geotextile fabric between the sand bed and the bottom underdrain system.

An impermeable liner under the facility may also be needed if the filtered runoff requires additional treatment to remove soluble groundwater pollutants, or in cases where additional groundwater protection is mandated. The variations of a sand filter include a basic or large sand filter, sand filter with level spreader, sand filter vault, and linear sand filter. (See Figure 5.8.1 for a basic sand filter.)

BMP T5.80 Basic sand filter: UIC regulations do not apply to these facilities unless an under-drainage system with perforated pipe is included in the design and then – provided that the design, operation, and maintenance criteria in this section are met – only the registration requirement would apply. See section 5.6.

BMP T5.81 Large sand filter: UIC regulations do not apply to these facilities if the outlet structure discharges exclusively to a conveyance system and(or) to surface water. However, the UIC guidelines in section 5.6 do apply to these facilities if the outlet structure discharges into the ground, and then – provided that the design, operation, and maintenance criteria in this section are met – only the registration requirement would apply. See section 5.6.

5.8.2 Performance Objectives

BMP T5.80 Basic Sand Filter

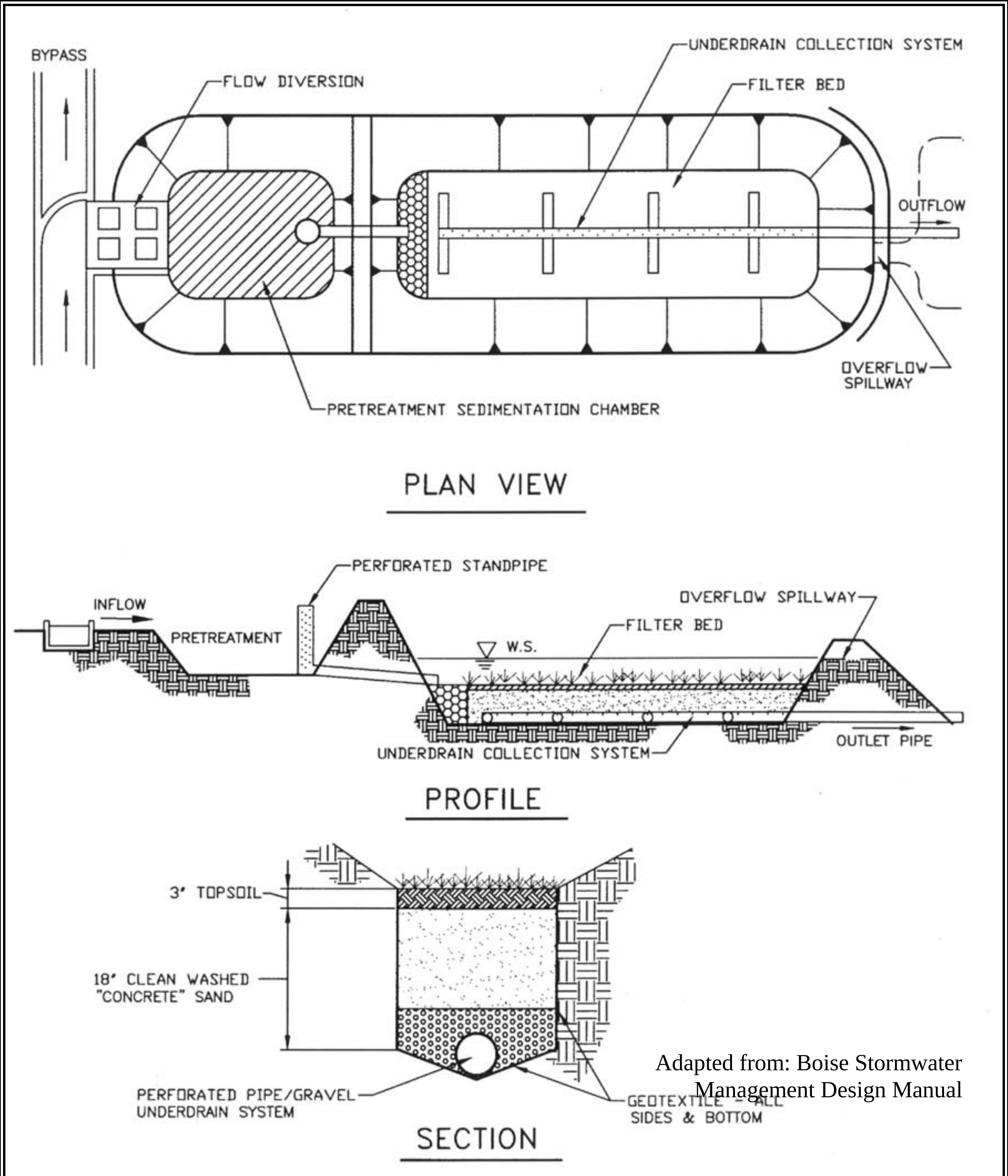
Basic sand filters are expected to achieve the performance goals for Basic Treatment. Based upon experience in King County and Austin, Texas basic sand filters should be capable of achieving the following average pollutant removals:

80 percent TSS at influent Event Mean Concentrations (EMCs) of 30-300 mg/L (King County, 1998) (Chang, 2000) oil and grease to below 10 mg/L daily average and 15 mg/L at any time, with no ongoing or recurring visible sheen in the discharge.

BMP T5.81 Large Sand Filter

Large sand filters are expected to remove at least 50% of the total phosphorous compounds (as TP) by collecting and treating 95% of the runoff volume (ASCE and WEF, 1998).

Figure 5.8.1 Sand Filter



Adapted from: Boise Stormwater Management Design Manual

5.8.3 Application and Limitations

Sand filtration can be used in most residential, commercial, and industrial developments where debris, heavy sediment loads, and oils and greases will not clog or prematurely overload the sand, or where adequate pretreatment is provided for these pollutants. Specific applications include residential subdivisions, parking lots for commercial and industrial establishments, gas stations, high-use sites, high-density multi family housing, roadways, and bridge decks.

Sand filters should be located off-line before or after detention. Sand filters are also suited for locations with space constraints in retrofit, and new/re-development situations. Overflow or bypass structures must be carefully designed to handle the larger storms. An off-line system is sized to treat 90% of the annual runoff volume. If a project must comply with Core Element #6, Flow Control, the flows bypassing the filter and the filter discharge must be routed to a retention/detention facility or other appropriate flow control BMP (for example, infiltration BMPs such as infiltration trenches or drywells)

Pretreatment is necessary to reduce velocities to the sand filter and remove debris, floatables, large particulate matter, and oils. In high water table areas adequate drainage of the sand filter may require additional engineering analysis and design considerations. Surface filters will not provide treatment in the winter if the ground is frozen, but may still provide adequate treatment during warmer months. An underground filter should be considered in areas subject to freezing conditions (Urbonas, 1997).

5.8.4 Site Suitability

The following site characteristics should be considered in siting a sand filtration system:

- Space availability, including a presettling basin
- Sufficient hydraulic head, at least 4 feet from inlet to outlet
- Average winter conditions at the project site do not create snow or ice conditions that prevent the filter from operating as designed
- Adequate Operation and Maintenance capability including accessibility for O & M
- Sufficient pretreatment of oil, debris, and solids in the tributary runoff

5.8.5 Design Criteria

Objective: To capture and treat the Water Quality Design Storm volume (when using the Simple Sizing Method described below). Off-line sand filters can be located either upstream or downstream of detention facilities. On-line sand filters should only be located downstream of detention.

Simple Sizing Method This method applies to the off-line placement of a sand filter upstream or downstream of detention facilities. A conservative design approach is provided below using a routing adjustment factor that does not require flow routing computations through the filter. An alternative simple approach for off-line placement downstream of detention facilities is to route the full 2-year release rate from the detention facility (sized for duration control) to a sand filter with sufficient surface area to infiltrate at that flow rate.

Basic Sand Filter For sizing a Basic Sand Filter, a 0.7 routing adjustment factor is applied to compensate for routing through the sand bed at the maximum pond depth. A flow splitter should be designed to route the water quality design flow rate to the sand filter.

Large Sand Filter: For sizing a Large Sand Filter, use the same procedure as outlined above for the Basic Sand Filter. Then apply a scale-up factor of 1.6 to the surface area. This is considered a reasonable average for various impervious tributary sources. For a Large Sand Filter the flow splitter upstream or downstream of the detention facility should be designed to route the flow rate associated with conveying 95% of the annual runoff volume to the sand filter. Use the standard water quality design flow rate multiplied by 1.2.

Note: *An overflow should be included in the design of the sand filter pond. The overflow height should be at the maximum hydraulic head of the pond above the sand bed.*

Example calculation using the simple sizing method and a routing adjustment factor.

Design Specifications:

Background The sizing of the sand filter is based on routing the design runoff volume through the sand filter and using Darcy's Law to account for the increased flow through the sand bed caused by the hydraulic head variations in the pond above the sand bed. Darcy's Law is represented by the following equation:

$Q_{sf} = KiA_{sf} = FA_{sf}$ where: $i = (h+L)/L$

Therefore, $A_{sf}=Q_{sf}/Ki$

Also, $Q_{sf}=A_tQ_dR/t$

Substituting for Q_{sf}, $A_{sf}=A_tQ_dR/Kit$

Or, $A_{sf}=A_tQ_dR/ \{K(h+L)/Lt\}$

Or, $A_{sf}=A_tQ_dR/Ft$

Where:

Q_{sf} is the flow rate in cu. feet per day (or ft^3/sec.) at which runoff is filtered by the sand filter bed,

A_{sf} is the sand filter surface area (sq. ft.)

Q_d is the design storm runoff depth (ft.) for the water quality storm. It is estimated using the SCS Curve Number equations detailed in Chapter 4.

R is a routing adjustment factor. Use R = 0.7.

A_t is the tributary drainage area (sq. ft.)

K is the hydraulic conductivity of the sand bed. Use 2 ft./day or 1.0 inch/hour at full pre-sedimentation

i is the hydraulic gradient of the pond above the filter; (h+L)/L, (ft/ft)

F=Ki is the filtration rate, feet/day (or inches per hour)

d is the maximum sand filter pond depth, and h = d/2 in ft.

t is the recommended maximum drawdown time of 24 hours from the completion of inflow into the sand filter pond (assume ponded pre-settling basin) of a discrete storm event to the completion of outflow from the sand filter underdrain of that same storm event.

L is the sand bed depth; typically 1.5 ft.

Given condition:

Sedimentation basin fully ponded and no pond water above sand filter

(Full sedimentation prior to sand filter-24 hours residence of WQ storm runoff)

A_t = 10 acres is tributary drainage area

Q_d = 0.92 inches (0.0767 ft.), for Yakima Rainfall

with Curve Number = 96.2 for 85% impervious and 15% grass tributary surfaces

R = 0.7, the routing adjustment factor

Maximum drawdown time through sand filter, 24 hours

Maximum pond depth above sand filter, example at 3 and 6 feet,

h = 1.5 and 3 feet

Design Hydraulic Conductivity of basic sand filter, K, 2.0 feet/day (1 inch/hour)

Using Design Equation

$A_{sf} = A_{sf} = A_t Q_d R / \{K(h+L)/Lt\}$

At pond depth of 3 feet:

A_{sf} = (10 acres)(43,560 ft^2/acre)(0.0767 ft)(0.7)/ {(2.0 ft/day)(1.5 ft + 1.5 ft)/(1.5 ft) (1 day)}= 5,846 square feet

Therefore A_{sf} for Basic Sand Filter becomes:

5,846 square feet at pond depth of 3 feet

Additional Design Information

1. Runoff to be treated by the sand filter must be pretreated (e.g., pre-settling basin, depending on pollutants) to remove debris and other solids, and oil from high use sites.
2. Inlet bypass and flow spreading structures (e.g., flow spreaders, weirs or multiple orifice openings) should be designed to capture the applicable design flow rate, minimize turbulence, and to spread the flow uniformly across the surface of the sand filter. Stone riprap or other energy dissipation devices should be installed to prevent gouging of the sand medium and to promote uniform flow. Include emergency spillway or overflow structures.
3. The following are design criteria for the underdrain piping: *(types of underdrains include: a central collector pipe with lateral feeder pipes, or, a geotextile drain strip in an 8-inch gravel backfill or drain rock bed, or, longitudinal pipes in an 8-inch gravel backfill or drain rock with a collector pipe at the outlet end.)*
   - Upstream of detention underdrain piping should be sized to handle double the two-year design storm. Downstream of detention the underdrain piping should be sized for the two-year design storm. In both instances there should be at least one (1) foot of hydraulic head above the invert of the upstream end of the collector pipe.
   - Internal diameters of underdrain pipes should be a minimum of six (6) inches and two rows of ½-inch holes spaced 6 inches apart longitudinally (maximum), with rows 120 degrees apart (laid with holes downward). Maximum perpendicular distance between two feeder pipes must be 15 feet. All piping is to be schedule 40 PVC or greater wall thickness. Drain piping could be installed in basin and trench configurations. Minimum underdrain size should be 8 inches in diameter if filter is subject to freezing for a month or more.
   - Main collector underdrain pipe should be at a slope of 0.5 percent minimum (1% if subject to freezing for a month or more.)
   - A geotextile fabric must be used between the sand layer and drain rock or gravel and placed so that 1 inch of drain rock/gravel is above the fabric. Drain rock should be 0.75-1.5 inch rock or gravel backfill, washed free of clay and organic material. Increase gravel depth at base of filter to 18 inches if subject to freezing for a month or more.
   - Cleanout wyes with caps or junction boxes must be provided at both ends of the collector pipes. Cleanouts must extend to the

surface of the filter. A valve box must be provided for access to the cleanouts. Access for cleaning all underdrain piping should be provided. This may consist of installing cleanout ports, which tee into the underdrain system and surface above the top of the sand bed. To facilitate maintenance of the sand filter, an inlet shutoff/bypass valve is recommended.

Note: *Other equivalent energy dissipaters can be used if needed.*

4. Sand Specification The sand in a filter must consist of a medium sand meeting the size gradation (by weight) given in Table 5.8.1 below. The contractor must obtain a grain size analysis from the supplier to certify that the No. 100 and No. 200 sieve requirements are met. *(Note: Standard backfill for sand drains, Wa. Std. Spec. 9-03.13, does not meet this specification and should not be used for sand filters.)*

Table 5.8.1 - Sand Medium Specification

U.S. Sieve Number	Percent Passing
4	95-100
8	70-100
16	40-90
30	25-75
50	2-25
100	<4
200	<2

Source: King County Surface Water Design Manual, September 1998

5. Impermeable Liners for Sand Bed Bottom: Impermeable liners are generally required for soluble pollutants such as metals and toxic organics and where the underflow could cause problems with structures. Impermeable liners may be clay, concrete, or geomembrane. Clay liners should have a minimum thickness of 12 inches and meet the specifications give in Table 5.8.2.

Table 5.8.2 - Clay Liner Specifications

Property	Test Method	Unit	Specification
Permeability	ASTM D-2434	cm/sec	$1 \times 10^{-6 \text{ max.}}$
Plasticity Index of Clay	ASTM D-423 & D-424	Percent	Not less than 15
Liquid Limit of Clay	ASTM D-2216	Percent	Not less than 30
Clay Particles Passing	ASTM D-422	Percent	Not less than 30
Clay Compaction	ASTM D-2216	Percent	95% of Standard Proctor Density

Source: City of Austin, 1988

If a geomembrane liner is used it should have a minimum thickness of 30 mils and be ultraviolet resistant. The geomembrane liner should be protected from puncture, tearing, and abrasion by installing geotextile fabric on the top and bottom of the geomembrane.

Concrete liners may also be used for sedimentation chambers and for sedimentation and sand filtration facilities less than 1,000 square feet in area. Concrete should be 5 inches thick Class A or better and should be reinforced by steel wire mesh. The steel wire mesh should be 6 gauge wire or larger and 6-inch by 6-inch mesh or smaller. An "Ordinary Surface Finish" is required. When the underlying soil is clay or has an unconfined compressive strength of 0.25 ton per square foot or less, the concrete should have a minimum 6-inch compacted aggregate base. This base must consist of coarse sand and river stone, crushed stone or equivalent with diameter of 0.75 to 1 inch.

If an impermeable liner is not required, then a geotextile fabric liner should be installed that retains the sand unless the sand filter has been excavated to bedrock.

If an impermeable liner is not provided, then an analysis should be made of possible adverse effects of seepage zones on ground water, and near building foundations, basements, roads, parking lots and sloping sites. Sand filters without impermeable liners should not be built on fill sites and should be located at least 20 feet downslope and 100 feet upslope from building foundations.

6. Include an access ramp with a slope not to exceed 7:1, or equivalent, for maintenance purposes at the inlet and the outlet of a surface filter. Consider an access port for inspection and maintenance.
7. Side slopes for earthen/grass embankments should not exceed 3:1 to facilitate mowing.
8. High groundwater may damage underground structures or affect the performance of filter underdrain systems. There should be sufficient clearance (at least 2 feet is recommended) between the seasonal high groundwater level (highest level of ground water observed) and the bottom of the sand filter to obtain adequate drainage.
9. A sport-field sod, grown in sand, may be used on the sand surface. No other soil may be used due to the high clay content in most sod soils. No topsoil may be added to sand filter beds because fine-grained materials (e.g., silt and clay) reduce the hydraulic capacity of the filter.

5.8.6 Construction Criteria

No runoff should enter the sand filter prior to completion of construction and approval of site stabilization by the responsible inspector. Construction runoff may be routed to a pretreatment sedimentation facility, but discharge from sedimentation facilities should bypass downstream sand filters. Careful level placement of the sand is necessary to avoid formation of voids within the sand that could lead to short-circuiting, (particularly around penetrations for underdrain cleanouts) and to prevent damage to the underlying geomembranes and underdrain system. Over-compaction should be avoided to ensure adequate filtration capacity. Sand is best placed with a low ground pressure bulldozer (4 psig or less). After the sand layer is placed, water settling is recommended. Flood the sand with 10-15 gallons of water per cubic foot of sand.

5.8.7 Maintenance Criteria

Inspections of sand filters and pretreatment systems should be conducted every 6 months and after storm events as needed during the first year of operation, and annually thereafter if filter performs as designed. Repairs should be performed as necessary. Suggestions for maintenance include:

Accumulated silt and debris on top of the sand filter should be removed when their depth exceeds ½ inch. The silt should be scraped off during dry periods with steel rakes or other devices. Once sediment is removed, the design permeability of the filtration media can typically be restored by then striating the surface layer of the media. Finer sediments that have penetrated deeper into the filtration media can reduce the permeability to unacceptable levels, necessitating replacement of some or all of the sand.

Sand replacement frequency is not well established and will depend on suspended solids levels entering the filter (the effectiveness of the pretreatment BMP can be a significant factor).

Frequent overflow into the spillway or overflow structure or slow drawdown are indicators of plugging problems. A sand filter should empty in 24 hours following a storm event (24 hours for the pre-settling chamber), depending on pond depth. If the hydraulic conductivity drops to one (1) inch per hour corrective action is needed, e.g.:

- Scraping the top layer of fine-grain sediment accumulation (mid-winter scraping is suggested)
- Removing of vegetation
- Aerating the filter surface
- Tilling the filter surface (late-summer rototilling is suggested)
- Replacing the top 4 inches of sand
- Inspecting geotextiles for clogging
- For sand filters with sport sod/grass cover, removing and replacing sod as appropriate. Sod removal may not be necessary for aeration of top of filter sand.

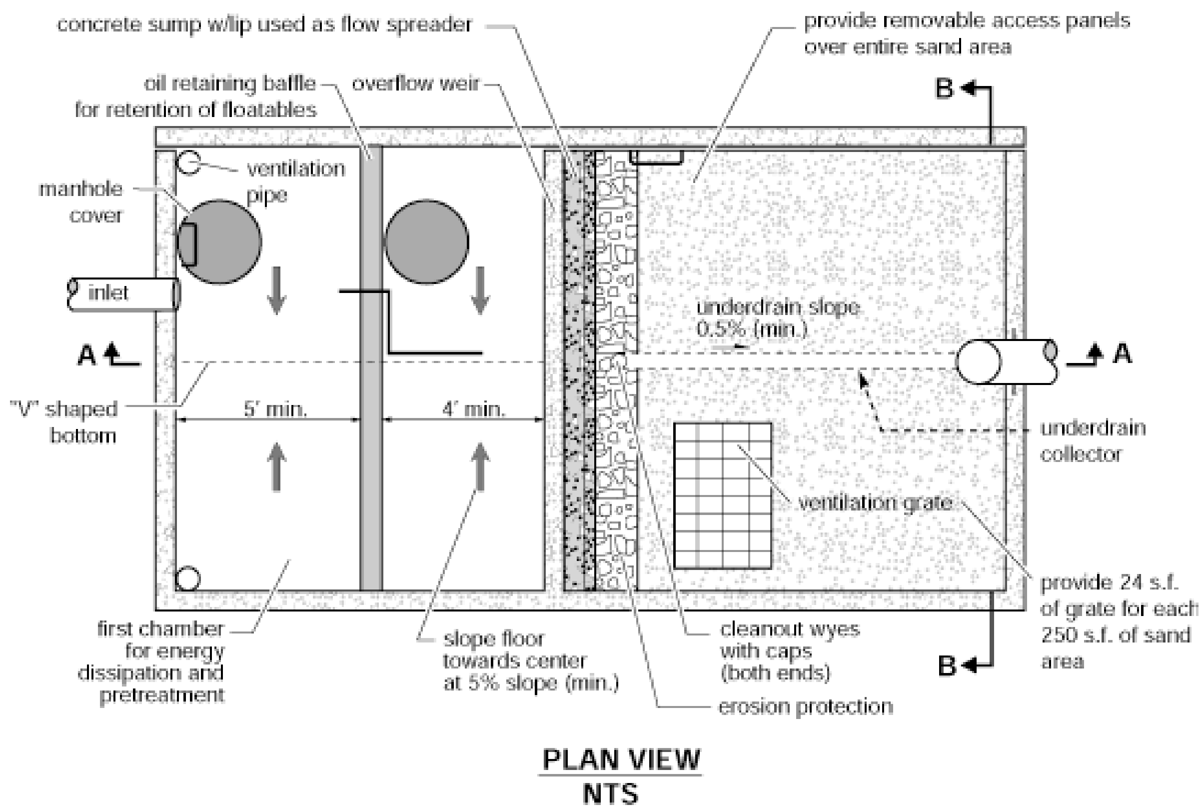
Rapid drawdown in the sand bed (greater than 12 inches per hour) indicates short-circuiting of the filter. Inspect the cleanouts on the underdrain pipes and along the base of the embankment for leakage.

Drawdown tests for the sand bed could be conducted, as needed, during the wet season. These tests can be conducted by allowing the filter to fill (or partially fill) during a storm event, then measuring the decline in water level over a 4-8 hour period. An inlet and an underdrain outlet valve would be necessary to conduct such a test.

Formation of rills and gullies on the surface of the filter indicates improper function of the inlet flow spreader or poor sand compaction. Check for accumulation of debris on or in the flow spreader and refill rills and gullies with sand.

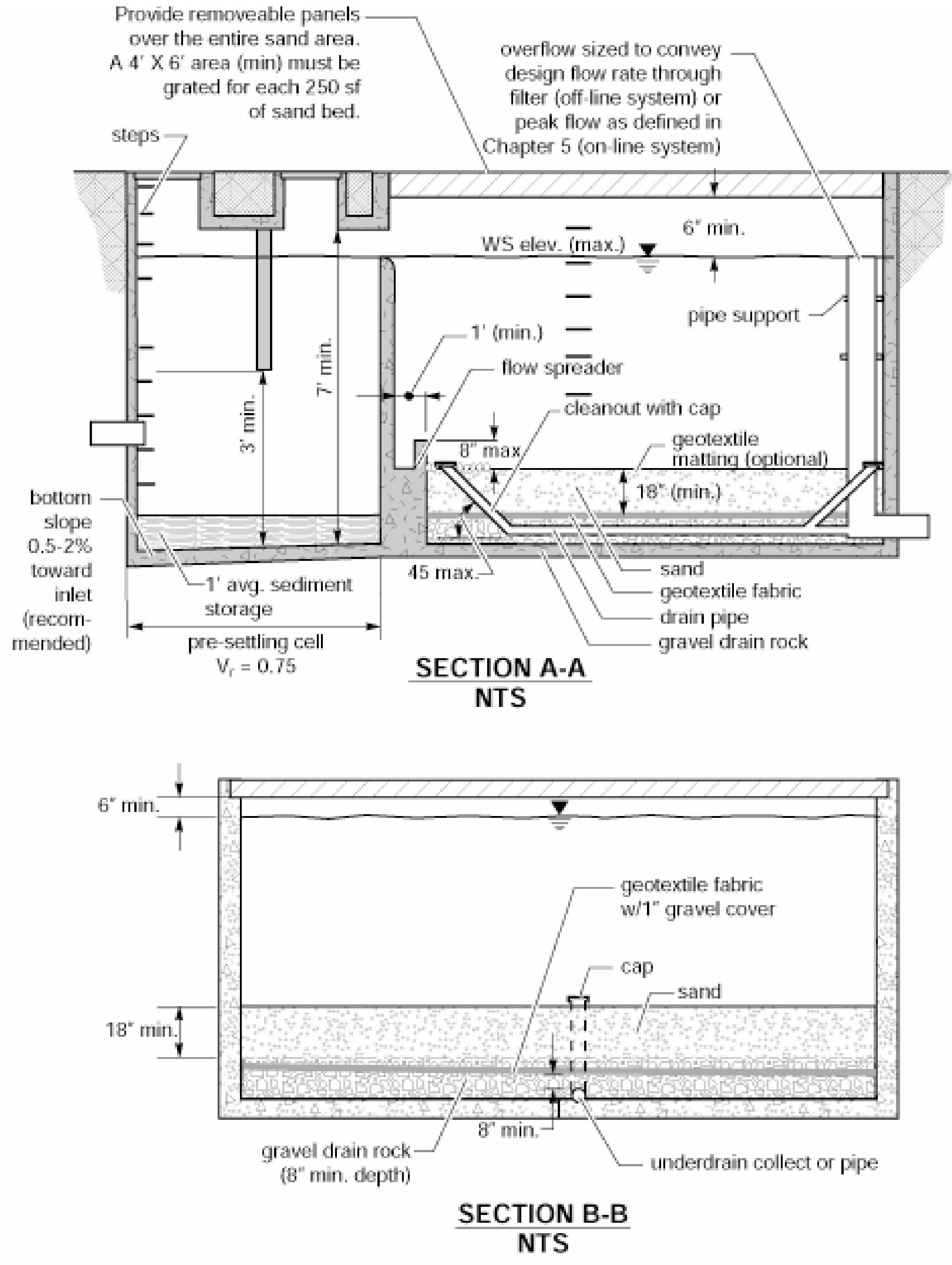
Avoid driving heavy equipment on the filter to prevent compaction and rut formation.

Figure 5.8.2a Sand Filter Vault



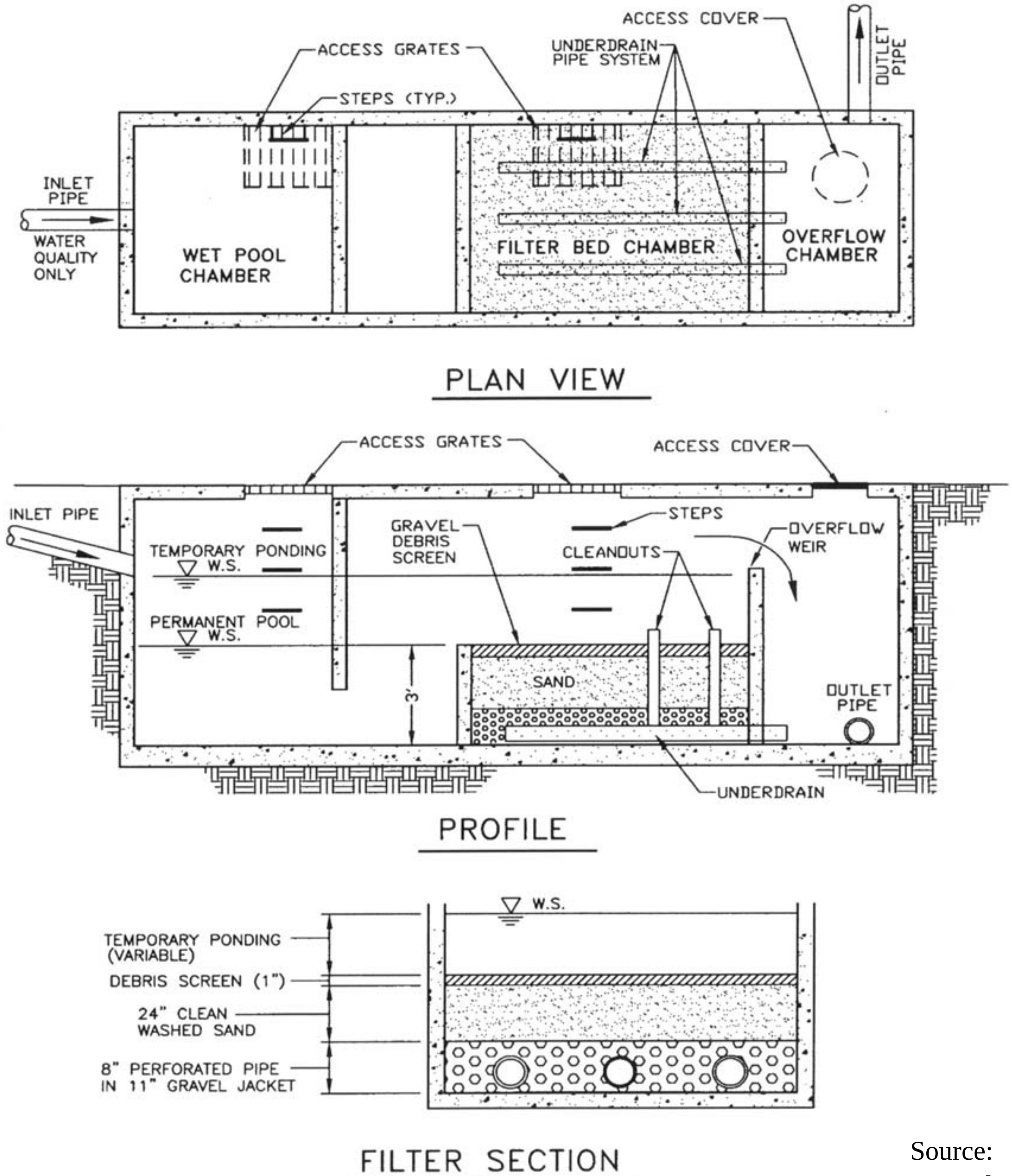
Source: King County Surface Water Manual

Figure 5.8.2b Sand Filter Vault (continued)



Source: King County Surface Water Manual

Figure 5.8.3 Sand Filter Vault (also called underground sand filter)



Source:
Boise Stormwater Manual

5.8.8 Sand Filtration Facilities

BMP T5.82 Sand Filter Vault

Description

See Figures 5.8.2a and b: A sand filter vault is similar to an open sand filter except that the sand layer and under-drains are installed below grade in a vault. It consists of pre-settling and sand filtration cells.

UIC regulations do not apply to these facilities unless a pond is deeper than it is wide at the ground surface, and then – provided that the design, operation, and maintenance criteria in this section are met – only the registration requirement would apply. See section 5.6.

Applications and Limitations

- Use where space limitations preclude above-ground facilities
- Not suitable where high water table and heavy sediment loads are expected
- An elevation difference of 4 feet between inlet and outlet is needed

Additional Design Criteria for Vaults

- Vaults may be designed as off-line systems or on-line for small drainages
- In an off-line system, a diversion structure should be installed to divert the design flow rate into the sediment chamber and bypass the remaining flow to detention/retention (if necessary to meet Core Element #6), or to surface water.
- Optimize sand inlet flow distribution with minimal sand bed disturbance. A maximum of 8-inch distance between the top of the spreader and the top of the sand bed is suggested. Flows may enter the sand bed by spilling over the top of the wall into a flow spreader pad or alternatively a pipe and manifold system may be used. Any pipe and manifold system must retain the required permanent pool volume in the first cell, minimize turbulence, and be readily maintainable.
- If an inlet pipe and manifold system is used, the minimum pipe size should be 8 inches. Multiple inlets are recommended to minimize turbulence and reduce local flow velocities.
- Erosion protection must be provided along the first foot of the sand bed adjacent to the spreader. Geotextile fabric secured on the surface of the sand bed, or equivalent method, may be used.
- The filter bed should consist of a sand top layer, and a geotextile fabric second layer with an underdrain system.
- Design the pre-settling cell for sediment collection and removal. A V-shaped bottom, removable bottom panels, or equivalent sludge

handling system should be used. One foot of sediment storage in the pre-settling cell must be provided.

- The pre-settling chamber should be constructed to trap oil and trash. This chamber is usually connected to the sand filtration chamber with an invert elbow or underflow baffle to protect the filter surface from oil and trash.
- If a retaining baffle is necessary for oil/floatables in the pre-settling cell, it must extend at least one foot above to one foot below the design flow water level. Provision for the passage of flows in the event of plugging must be provided. Access opening and ladder must be provided on both sides of the baffle.
- To prevent anoxic conditions, a minimum of 24 square feet of ventilation grate should be provided for each 250 square feet of sand bed surface area. For sufficient distribution of airflow across the sand bed, grates may be located in one area if the sand filter is small, but placement at each end is preferred. Small grates may also be dispersed over the entire sand bed area.
- Provision for access is the same as for wet vaults. Removable panels must be provided over the sand bed.
- Sand filter vaults must conform to the materials and structural suitability criteria specified for wet vaults.
- Provide a sand filter inlet shutoff/bypass valve for maintenance.
- A geotextile fabric over the entire sand bed may be installed that is flexible, highly permeable, three-dimensional matrix, and adequately secured. This is useful in trapping trash and litter.

BMP T5.83 Linear Sand Filter

Description

Linear sand filters (Figure 5.8.4) are typically long, shallow, two-celled, rectangular vaults. The first cell is designed for settling coarse particles, and the second cell contains the sand bed. Stormwater flows into the second cell via a weir section that also functions as a flow spreader.

UIC regulations apply to these facilities. Provided that the design, operation, and maintenance criteria in this section are met, only the registration requirement would apply. See section 5.6.

Application and Limitations

- Applicable in long narrow spaces such as the perimeter of a paved surface.
- As a part of a treatment train as downstream of a filter strip, upstream of an infiltration system, or upstream of a wet pond or a biofilter for oil control.

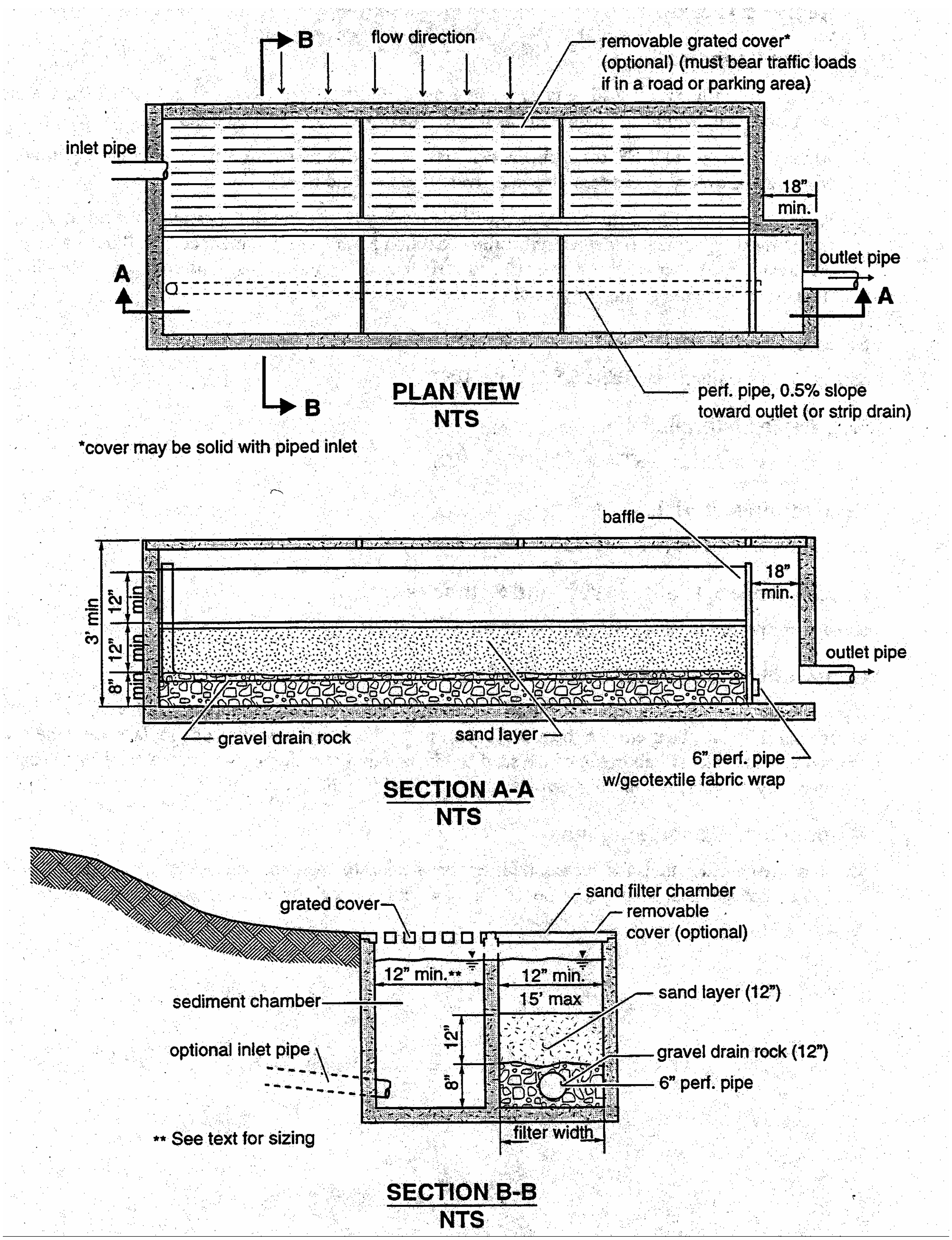
- To treat small drainages (less than 2 acres of impervious area).
- To treat runoff from high-use sites for TSS and oil/grease removal, if applicable.

Additional Design Criteria for Linear Sand Filters

- The two cells should be divided by a divider wall that is level and extends a minimum of 12 inches above the sand bed.
- Stormwater may enter the sediment cell by sheet flow or a piped inlet.
- The width of the sand cell must be 1 foot minimum to 15 feet maximum.
- The sand filter bed must be a minimum of 12 inches deep and have an 8-inch layer of drain rock with perforated drainpipe beneath the sand layer.
- The drainpipe must be 6-inch diameter minimum and be wrapped in geotextile and sloped a minimum of 0.5 percent.
- Maximum sand bed ponding depth: 1 foot.
- Must be vented as for sand filter vaults.
- Linear sand filters must conform to the materials and structural suitability criteria specified for wet vaults.
- Set sediment cell width as follows:

Sand filter width (w), in inches	12-24	24-48	48-72	72+
Sediment cell width, in inches	12	18	24	w/3

Figure 5.8.4 Linear Sand Filter



Source: King County Surface Water Manual

5.9 Evaporation Ponds

Evaporation ponds are ponds with no outlet which settle out the suspended solids, heavy metals, and hydrocarbons and may be used for water quality treatment. See Section 6.4 for details on designing evaporation ponds.

5.10 Oil and Water Separators

This section provides a discussion of oil and water separators, including their application and design criteria. BMPs are described for baffle type and coalescing plate separators.

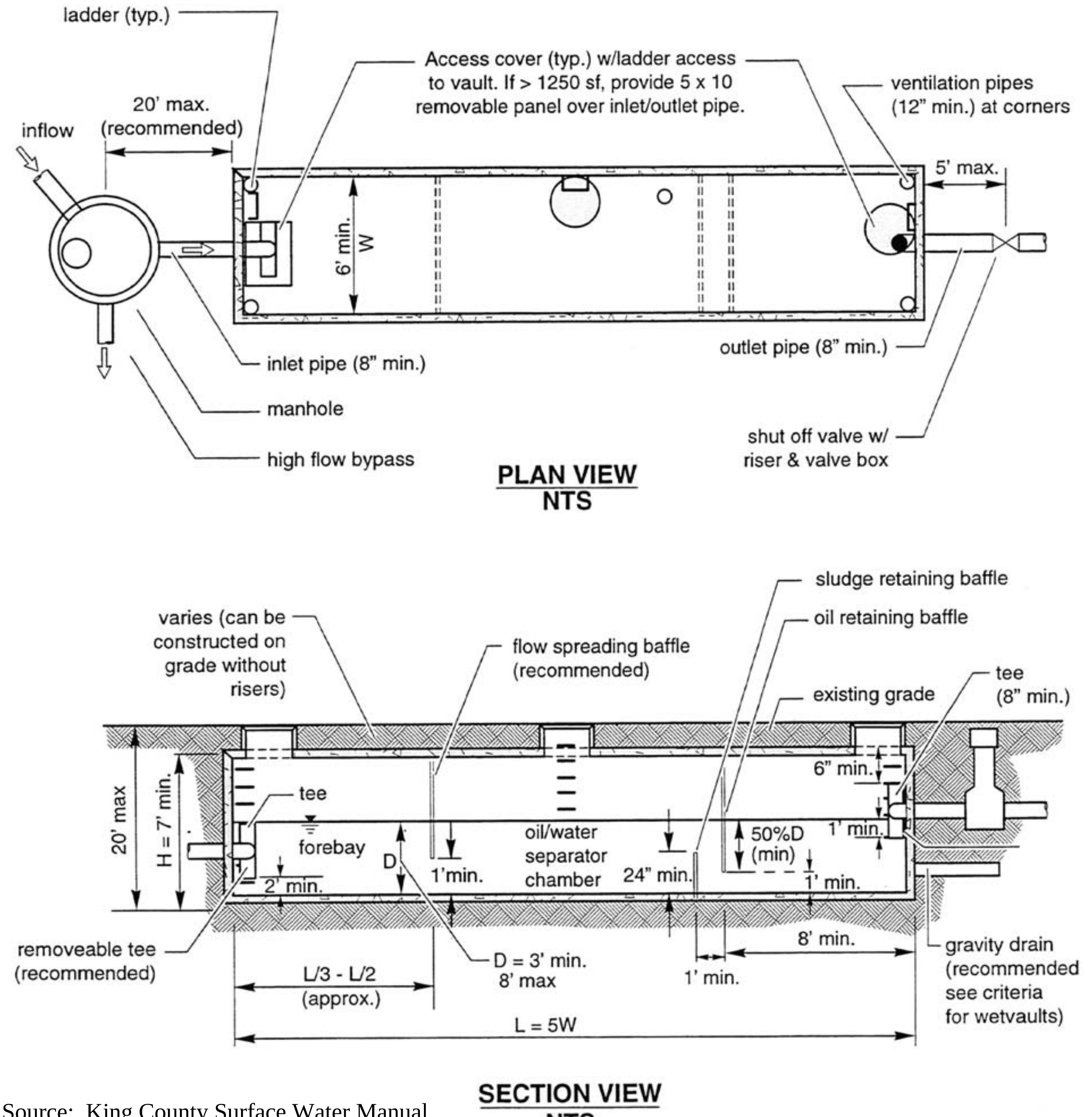
5.10.1 Purpose of Oil and Water Separators

To remove oil and other water-insoluble hydrocarbons and settleable solids from stormwater runoff.

5.10.2 Description

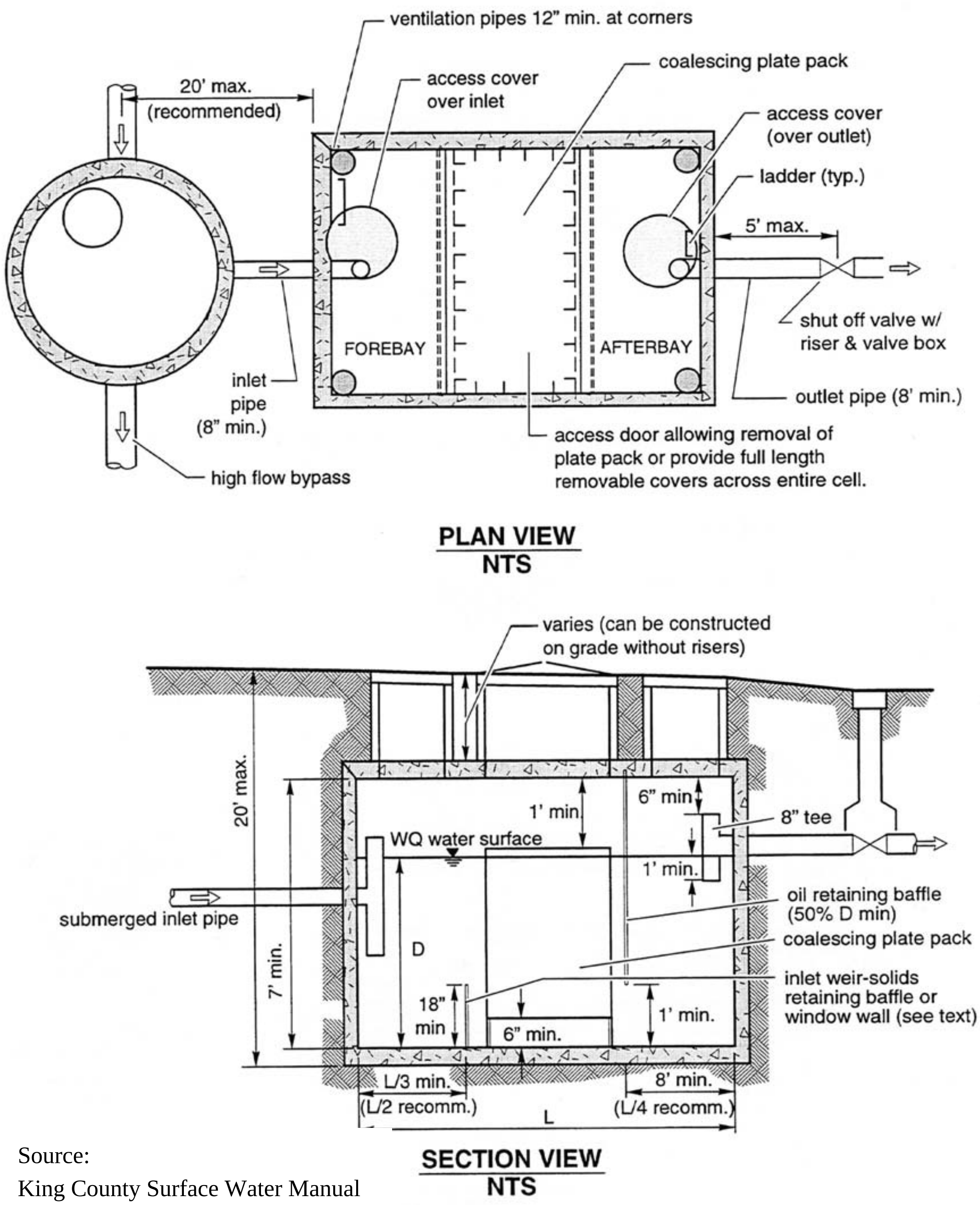
Oil and water separators are typically the American Petroleum Institute (API) (also called baffle type) (American Petroleum Institute, 1990) or the coalescing plate (CP) type using a gravity mechanism for separation. See Figures 5.10.1 and 5.10.2. Oil removal separators typically consist of three bays; forebay, separator section, and the afterbay. The CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates. A spill control (SC) separator (Figure 5.10.3) is a simple catchbasin with a T-inlet for temporarily trapping small volumes of oil. The spill control separator is included here for comparison only and is not designed for, or to be used for, treatment purposes.

Figure 5.10.1 API (Baffle Type) Separator



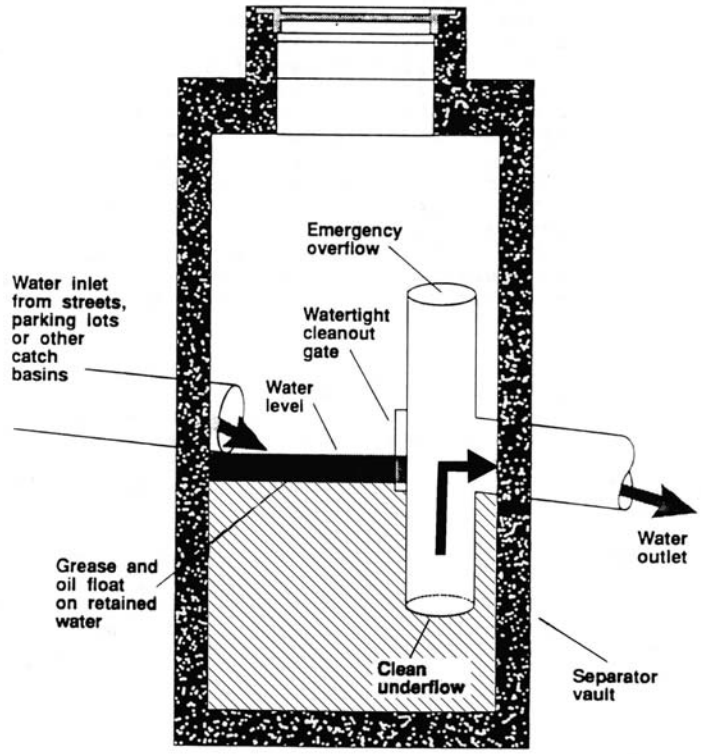
Source: King County Surface Water Manual

Figure 5.10.2 Coalescing Plate Separator



Source:
King County Surface Water Manual

Figure 5.10.3 Spill Control Separator (not for oil treatment)



Source: Ecology's Stormwater Management Manual, 1992

5.10.3 Performance Objectives

Oil and water separators should be designed to remove oil and TPH down to 15 mg/L at any time and 10 mg/L on a 24-hr average, and produce a discharge that does not cause an ongoing or recurring visible sheen in the stormwater discharge or in the receiving water (see also Section 5.2).

5.10.4 Applications/Limitations

The following are potential applications of oil and water separators where free oil is expected to be present at treatable high concentrations and sediment will not overwhelm the separator. (Seattle METRO, 1990; Watershed Protection Techniques, 1994; King County Surface Water Management, 1998) For low concentrations of oil, other treatments may be more applicable. These include sand filters and emerging technologies.

Facilities that would require oil control BMPs under the high-use site threshold described in Chapter 2 – Core Elements include parking lots at convenience stores, fast food restaurants, grocery stores, shopping malls, discount warehouse stores, banks, truck fleets, auto and truck dealerships, and delivery and commercial and industrial areas including petroleum storage yards, vehicle maintenance facilities, manufacturing areas, airports, utility areas (water, electric, gas), and fueling stations.

Without intense maintenance, oil/water separators may not be sufficiently effective in achieving oil and TPH removal down to required levels.

Pretreatment should be considered if the level of TSS in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the separator.

For inflows from small drainage areas (fueling stations, maintenance shops, etc.), a coalescing plate (CP) type separator is typically considered, due to space limitations. However, if plugging of the plates is likely, then a new design basis for the baffle type API separator may be considered on an experimental basis.

5.10.5 Site Suitability

Consider the following site characteristics:

- Sufficient land area
- Adequate TSS control or pretreatment capability
- Compliance with environmental objectives
- Adequate influent flow attenuation and/or bypass capability
- Sufficient access for operation and maintenance (O & M)

5.10.6 Design Criteria-General Considerations

There is concern that oil/water separators used for stormwater treatment have not performed to expectations.(Watershed Protection Techniques, 1994; Schueler, Thomas R., 1990) Therefore, emphasis should be given to proper application (see Section 5.4), design, O & M, (particularly sludge and oil removal) and prevention of CP fouling and plugging.(US Army of Engineers, 1994). Other treatment systems, such as sand filters and emerging technologies, should be considered for the removal of insoluble oil and TPH.

The following are design criteria applicable to API and CP oil/water separators:

- If practicable, determine oil/grease (or TPH) and TSS concentrations, lowest temperature, pH; and empirical oil rise rates in the runoff, and the viscosity, and specific gravity of the oil. Also determine whether the oil is emulsified or dissolved. (Washington State Department of Ecology, 1995) Do not use oil/water separators for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.
- Locate the separator off-line and bypass flows in excess of 2.15 times the Water Quality design flow rate.

- Use only impervious conveyances for oil contaminated stormwater.
- Specify appropriate performance tests after installation and shakedown, and/or certification by a professional engineer that the separator is functioning in accordance with design objectives. Expeditious corrective actions must be taken if it is determined the separator is not achieving acceptable performance levels.
- Add pretreatment for TSS that could cause clogging of the CP separator or otherwise impair the long-term effectiveness of the separator.

Criteria for Separator Bays

- Size the separator bay for the Water Quality design flow rate x a correction factor of 2.15.
- To collect floatables and settleable solids, design the surface area of the forebay at 20 ft^2 per 10,000 ft^2 of area draining to the separator. The length of the forebay should be 1/3-1/2 of the length of the entire separator. Include roughing screens for the forebay or upstream of the separator to remove debris, if needed. Screen openings should be about 3/4 inch.
- Include a submerged inlet pipe with a turn-down elbow in the first bay at least two feet from the bottom. The outlet pipe should be a Tee, sized to pass the design peak flow and placed at least 12 inches below the water surface.
- Include a shutoff mechanism at the separator outlet pipe. (King County Surface Water Management, 1998)
- Use absorbents and/or skimmers in the afterbay as needed.

Criteria for Baffles

- Oil retaining baffles (top baffles) should be located at least at ¼ of the total separator length from the outlet and should extend down at least 50% of the water depth and at least 1 foot from the separator bottom.
- Baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

5.10.7 Oil and Water Separator BMPs

Two BMPs are described in this section. BMP T5.10 for baffle type separators and BMP T6.11 for coalescing plate separators.

UIC regulations do not apply to these facilities if the outlet structure discharges exclusively to a conveyance system and(or) to surface water. However, the UIC regulations do apply to these facilities if the outlet structure discharges into the ground, and then – provided that the design, operation, and maintenance criteria in this section are met – only the registration requirement would apply. See section 5.6.

BMP T5.100 API (Baffle type) Separator Bay

Design Criteria

The design criteria for small drainages are based on the design velocity, oil rise rate, residence time, width, depth, and length considerations. As a correction factor, the American Petroleum Institute (API) turbulence criterion is applied to increase the length.

Ecology is modifying the API criterion for treating stormwater runoff from small drainage areas (fueling stations, commercial parking lots, etc.) by using the design hydraulic horizontal velocity, V_h, for the design V_h/V_t ratio rather than the API minimum of $V_h/V_t = 15$. The API criterion appears applicable for greater than two acres of impervious drainage area. Performance verification of this design basis must be obtained during at least one wet season using the test protocol referenced in Section 5.12 for new technologies.

The following is the sizing procedure using the modified API criterion:

- Determine the oil rise rate, V_t, in cm/sec, using Stoke's Law (Water Pollution Control Federation, 1985), or empirical determination, or 0.033 ft./min for 60°F oil. The application of Stoke's Law to site-based oil droplet sizes and densities, or empirical rise rate determinations recognizes the need to consider actual site conditions. In those cases the design basis would not be the 60 micron droplet size and the 0.033 ft/min. rise rate.
- Stoke's Law equation for rise rate, V_t (cm/sec):

  $$V_t = g(\sigma_w - \sigma_o)D^2 / 18\eta_w)$$

  Where: g = gravitational constant (981 cm/sec^2)

  D = diameter of the oil particle in cm

  Use oil particle size diameter D=60 microns (0.006 cm)

  σ_w =0.999 gm/cc. at 32°F

  σ_o: Select conservatively high oil density, for example:
  if diesel oil @ $\sigma_o = 0.85$ gm/cc and motor oil @ $\sigma_o = 0.90$ can be present, then use $\sigma_o = 0.90$ gm/cc

  $\eta_w = 0.017921$ poise, gm/cm-sec at $T_w = 32$°F
  (See API Publication 421, February, 1990)
- Use the following separator dimension criteria:

  Separator water depth d = between 3 and 8 feet to minimize turbulence (API, 1990; US Army Corps of Engineers, 1994)

  Separator width w = between 6 and 20 feet (WEF & ASCE, 1998; King County Surface Water Management, 1998)

Depth to width ratio d/w = between 0.3 and 0.5 (API, 1990)

For stormwater inflow from drainages less than 2 acres:

- Determine V_t and select depth and width of the separator section based on above criteria.
- Calculate the minimum residence time (t_m) of the separator at depth (d):

$$t_m = d/V_t$$

- Calculate the horizontal velocity of the bulk fluid, V_h, vertical cross-sectional area, A_v, and actual design V_h/V_t (American Petroleum Institute, 1990; US Army Corps of Engineers, 1994).

  $V_h = Q/dw = Q/A_v$
  (V_h maximum at < 2.0 ft/min; American Petroleum Institute, 1990)

  Q = 2.15 times the water quality design flow rate in ft^3/min, at minimum residence time, t_m

  At V_h/V_t determine F, turbulence and short-circuiting factor (Appendix V-D of the SWMMWW) API F factors range from 1.28-1.74. (American Petroleum Institute, 1990)

- Calculate the minimum length of the separator section, l(s), using:

  $l(s) = FQt_m/wd = F(V_h/V_t)d$
  $l(t) = l(f) + l(s) + l(a)$
  $l(t) = l(t)/3 + l(s) + l(t)/4$

  Where:

  l(t) = total length of 3 bays
  l(f) = length of forebay
  l(a) = length of afterbay

- Calculate V = l(s)wd = FQtm, and Ah = wl(s)

  V = minimum hydraulic design volume
  A_h = minimum horizontal area of the separator

BMP T5.110 Coalescing Plate (CP) Separator Bay

Design Criteria

Calculate the projected (horizontal) surface area of plates needed using the following equation:

$$A_p = Q/V_t = Q/0.00386(\sigma_w - \sigma_o/\eta_w)$$

$$A_p = A_a(\text{cosine } b)$$

Where:

Q = the water quality design flow rate, ft^3/min

V_t = Rise rate of 0.033 ft/min, or empirical determination, or based on Stoke's Law

A_p = projected surface area of the plate in ft^2; .00386 is unit conversion constant

σ_w = density of water at 32º F

σ_o = density of oil at 32º F

A_a = actual plate area in ft^2 (one side only)

b = angle of the plates with the horizontal in degrees (usually varies from 45-60 degrees).

η_w = viscosity of water at 32º F

- Plate spacing should be a minimum of 3/4 in (perpendicular distance between plates). (WEF & ASCE, 1998; US Army Corps of Engineers, 1994; US Air Force, 1991; Jaisinghani, R., 1979)
- Select a plate angle between 45° to 60° from the horizontal.
- Locate plate pack at least 6 inches from the bottom of the separator for sediment storage.
- Add 12 inches minimum head space from the top of the plate pack and the bottom of the vault cover.
- Design inlet flow distribution and baffles in the separator bay to minimize turbulence, short-circuiting, and channeling of the inflow especially through and around the plate packs of the CP separator. The Reynolds Number through the separator bay should be <500 (laminar flow).
- Include forebay for floatables and afterbay for collection of effluent. (WEF & ASCE, 1998)
- The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 in. (King County Surface Water Management, 1998).
- Design plates for ease of removal, and cleaning with high-pressure rinse or equivalent.

5.10.8 Operation and Maintenance

- Prepare, regularly update, and implement an O&M manual for the oil/water separators.

- Inspect oil/water separators monthly during the wet season of October 1-June 30 (WEF & ASCE, 1998; Woodward-Clyde Consultants) to ensure proper operation, and, during and immediately after a large storm event of greater than or equal to 1 inch per 24 hours. In region 2, it is most important to check these facilities in the spring before the summer thunderstorm season begins; one annual check done at this time of year should be sufficient for oil/water separators in region 2.
- Clean oil/water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has accumulated during the dry season (Woodward-Clyde Consultants), after all spills and after a significant storm. Coalescing plates may be cleaned in-situ or after removal from the separator. An eductor truck may be used for oil, sludge, and wash water removal. (King County Surface Water Management, 1998) Replace wash water in the separator with clean water before returning it to service.
- Remove the accumulated oil when the thickness reaches 1 inch. Also remove sludge deposits when the thickness reaches 6 inches (King County Surface Water Management, 1998).
- Replace oil absorbent pads before their sorbed oil content reaches capacity.
- Train designated employees on appropriate separator operation, inspection, record keeping, and maintenance procedures.

See Appendix 5A for more detailed information.

5.11 Phosphorus Treatment and Metals Treatment

5.11.1 Phosphorus Treatment

Where Applied

Phosphorus treatment applies to projects within watersheds that have been determined by local governments, the Department of Ecology, or the USEPA to be sensitive to phosphorus and that are being managed to control phosphorus inputs from stormwater.

Performance Goal

The Phosphorus Treatment facility choices are intended to achieve a goal of 50% total phosphorus removal for a range of influent concentrations of 0.1 – 0.5 mg/l total phosphorus. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities), or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained. Ecology encourages the design and operation of treatment facilities that engage a bypass at flow rates higher than the water quality design flow rate. However, this is acceptable provided that the overall reduction in phosphorus loading (treated plus bypassed) is at least equal to that achieved with initiating bypass at the water quality design flow rate.

Phosphorus Treatment Options

Any one of the following options may be chosen to satisfy the phosphorus treatment requirement.

Infiltration with Appropriate Pretreatment – See Section 5.4.

Infiltration treatment – If infiltration is through soils meeting the minimum site suitability criteria for infiltration treatment (see Section 5.4), a presettling basin or a basic treatment facility can serve for pretreatment.

Infiltration preceded by Basic Treatment – If infiltration is through soils that do not meet the site suitability criteria for infiltration treatment, treatment must be provided by a basic treatment facility unless the soil and site fit the description in the next option below.

Infiltration preceded by Phosphorus Treatment – Requirements to be determined by TMDL.

Amended Sand Filter – See Section 5.12.

Note: *Processed steel fiber and crushed calcitic limestone are the only sand filter amendments for which Ecology has data that document increased dissolved metals removal. Though Ecology is interested in obtaining additional data on the effectiveness of these amendments, local governments may exercise their judgment on the extent to which to allow their use.*

Large Wetpond – See Section 5.7.

Media Filter Targeted for Phosphorus Removal – See Section 5.12.

Note: *The use of a Stormfilter™ with iron-infused media is approved for use in limited circumstances, provided a monitoring program consistent with adopted protocols is implemented.*

Two-Facility Treatment Trains – See Table 5.11.1. Note that if a filter is preceded by a wetpond, a horizontal rock filter may reduce transfer of algae from the pond to the filter.

Table 5.11.1 - Treatment trains for phosphorus removal

First Basic Treatment Facility	Second Treatment Facility
Biofiltration Swale	Basic Sand Filter or Sand Filter Vault
Vegetated Filter Strip	Linear Sand Filter (no presettling needed)
Linear Sand Filter	Filter Strip
Basic Wetpond	Basic Sand Filter or Sand Filter Vault
Wetvault	Basic Sand Filter or Sand Filter Vault
Basic Combined Detention and Wetpool	Basic Sand Filter or Sand Filter Vault
NOTE: See Section 5.2.3 (or Table 5.2.6) for Cold Weather Considerations and Table 5.2.4 for Arid and Semi-Arid Climate Considerations.	

5.11.2 Metals Treatment

Where Applied

Metals treatment is required for sites and uses determined in Core Element 5 to be subject to metals treatment requirements. Metals treatment is required for moderate- and high-use sites as defined in section 2.2.5 and sites that meet any of the following definitions and discharge to a non-exempt surface water:

- Industrial sites as defined by EPA (40 CFR 122.26(b)(14)) with benchmark monitoring requirements for metals; or industrial sites subject to handling, storage, production, or disposal of metallic products or other materials, particularly those containing arsenic, cadmium, chromium, copper, lead, mercury, nickel or zinc; or
- An urban road with expected ADT greater than 7,500; or a rural road or freeway with expected ADT greater than 15,000; or
- A commercial or industrial site with an expected trip end count equal to or greater than 40 vehicles per 1,000 square feet of gross building area; or a customer or visitor parking lot with equal to or greater than 100 trip ends; or on-street parking areas of municipal streets in commercial and industrial areas; or highway rest areas; or
- Runoff from metal roofs not coated with an inert, non-leachable material.

Discharges to nonfish-bearing streams are exempt from additional metals treatment requirements. Direct discharges to the main channels of the following rivers and direct discharges to the following lakes are exempt from metals treatment requirements: Banks Lake, Lake Chelan, Columbia River, Grande Ronde River, Kettle River, Klickitat River, Methow River, Moses Lake, Potholes Reservoir, Naches River, Okanogan River, Pend Oreille River, Similkameen River, Snake River, Spokane River, Wenatchee River, and Yakima River. Subsurface discharges via rule-authorized Underground Injection Control (UIC) facilities (see section 5.6) are also exempt from metals treatment requirements. Restricted residential and employee-only parking areas are exempt from metals treatment requirements unless subject to through traffic.

Areas of arterials and highways, multifamily, industrial and commercial project sites that do not discharge to fish-bearing streams or lakes or are identified in a storm drainage comprehensive plan or basin plan as subject to Basic Treatment requirements are not subject to Metals Treatment requirements. For developments with a mix of land use types, the Metals Treatment requirement shall apply when the runoff from the areas subject to the Metals Treatment requirement comprise 50% or more of the total runoff to a discharge location.

Performance Goal

The Metals Treatment facility choices are intended to provide a higher rate of removal of dissolved metals than Basic Treatment facilities. Due to the sparse data available concerning dissolved metals removal in stormwater treatment facilities, a specific numeric removal efficiency goal could not be established at the time of publication. Instead, Ecology relied on available nationwide and local data and knowledge of the pollutant removal mechanisms of treatment facilities to develop the list of options below. In addition, the choices are intended to achieve the Basic Treatment performance goal. The performance goal assumes that the facility is treating stormwater with dissolved copper typically ranging from 0.003 to 0.02 mg/l, and dissolved zinc ranging from 0.02 to 0.3 mg/l.

The performance goal applies to the water quality design storm volume or flow rate, whichever is applicable, and on an annual average basis. The incremental portion of runoff in excess of the water quality design flow rate or volume can be routed around the facility (off-line treatment facilities) or can be passed through the facility (on-line treatment facilities) provided a net pollutant reduction is maintained. Ecology encourages the design and operation of treatment facilities that engage a bypass at flow rates higher than the water quality design flow rate as long as the reduction in dissolved metals loading exceeds that achieved with initiating bypass at the water quality design flow rate.

Metals Treatment Options

Any one of the following options may be chosen to satisfy the Metals Treatment requirement:

<u>Infiltration with Appropriate Pretreatment</u> – See Section 5.4.

<u>Infiltration Treatment</u> **–** If infiltration is through soils meeting the minimum site suitability criteria for infiltration treatment (see Section 5.4), a presettling basin or a basic treatment facility can serve for pretreatment.

Infiltration preceded by Basic Treatment **–** If infiltration is through soils that do not meet the soil suitability criteria for infiltration treatment, treatment must be provided by a basic treatment facility unless the soil and site fit the description in the next option below.

Infiltration preceded by Metals Treatment **–** If the soils do not meet the soil suitability criteria and the infiltration site is within ¼ mile of a fish-bearing stream, a tributary to a fish-bearing stream, or a lake, treatment must be provided by one of the other treatment facility options listed below.

Large Sand Filter – See Section 5.8.

Amended Sand Filter – See Section 5.12.

Note: *Processed steel fiber and crushed calcitic limestone are the only sand filter amendments for which Ecology has data that document increased dissolved metals removal. Though Ecology is interested in obtaining additional data on the effectiveness of these amendments, local governments may exercise their judgment on the extent to which to allow their use.*

Two Facility Treatment Trains – See Table 5.11.2.

Table 5.11.2 -Treatment Trains for Dissolved Metals Removal

First Basic Treatment Facility	Second Treatment Facility
Biofiltration Swale	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Filter Strip	Linear Sand Filter with no pre-settling cell needed
Linear Sand Filter	Filter Strip
Basic Wetpond	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Wetvault	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Basic Combined Detention/Wetpool	Basic Sand Filter or Sand Filter Vault or Media Filter(1)
Basic Sand Filter or Sand Filter Vault with a presettling cell if the filter isn't preceded by a detention facility	Media Filter(1)
(1) The media must be of a nature that has the capability to remove dissolved metals effectively based on at least limited data. Ecology includes Stormfilter's ™ leaf compost and zeolite media in this category.	

5.12 Emerging Technologies

Emerging technologies are new technologies that have not been evaluated using approved protocols, but for which preliminary data indicate that they may provide a desirable level of stormwater pollutant removal.

5.12.1 Background

During the last ten years, new technologies have been under development to meet the needs of urban stormwater pollutant control. However, because no standardized statewide procedure for evaluating these technologies was available, local jurisdictions and commercial establishments have had to individually decide on their use. This resulted in differences in the criteria for accepting new technologies.

Some emerging technologies have already been installed in Washington as parts of treatment trains or as stand-alone systems for specific applications. In some cases, emerging technologies are appropriate to remove metals, hydrocarbons, and nutrients. Emerging technologies can also be used for retrofits and where land is unavailable for larger treatment systems.

5.12.2 Ecology Role in Evaluating Emerging Technologies

Ecology has developed a new technology evaluation program which is briefly described in this chapter. The program is based on reviewing engineering reports on the performance of new technologies and reporting the results at Ecology's web site.

This program includes:

- A Technical Review Committee (TRC) including representatives from local governments in eastern and western Washington that acts in an advisory capacity to provide recommendations to Ecology on the level of development of each technology.
- A web site with brief descriptions of each new technology, TRC recommendations, and Ecology's determinations of the levels of development of each technology at: http://www.ecy.wa.gov/programs/wq/stormwater/new_tech/

5.12.3 Local Government Evaluation of Emerging Technologies

Local governments should consider the following as they make decisions concerning the use of new stormwater technologies in their jurisdictions:

Remember the goal: The goal of any stormwater management program or BMP is to treat and release stormwater in a manner that does not harm beneficial uses. Compliance with water quality standards is one measure of determining whether beneficial uses will be harmed.

Exercise reasonable caution: It is important to be cautious with the use of emerging, unproven, technologies for new development and for retrofits. Before selecting a new technology for a limited application, the local government should review evaluation information based on an acceptable protocol.

An emerging technology must not be used for new development sites unless there are data indicating that its performance is expected to be reasonably equivalent to a Basic Treatment, or as part of a treatment train. Local governments can refer to Ecology's web site to obtain the latest performance verification of an emerging technology.

Local governments are encouraged to:

- Conduct a monitoring program, using an acceptable protocol, of those emerging technologies that have not been verified for limited or full-scale statewide use at Ecology's web site.
- Look for achieving acceptable performance objectives as specified in Section 5.1.

To achieve the goals of the Clean Water Act and the Endangered Species Act, local government may find it necessary to retrofit many, existing stormwater discharges. In retrofit situations, the use of any BMPs that make substantial progress toward these goals is a step forward and is encouraged by Ecology. To the extent practical, the performance of these BMPs should be evaluated, using approved protocols.

5.12.4 Testing Protocol

To properly evaluate new technologies, performance data must be obtained using an accepted protocol. A test protocol has been developed which serves to standardize the testing conditions. Sampling criteria, site and technology information, QA/QC, target pollutants, and evaluation report content are specified in the protocol.

Other protocols also may be used if they are deemed equivalent to the recommended Ecology testing protocol. Such protocols may be developed by local, state, or federal agencies.

5.12.5 Assessing Levels of Development of Emerging Technologies

Ecology has received several submittals from vendors to approve their new technologies for statewide applications. However, none of the submittals included performance information using the Ecology testing protocol or equivalent protocol. Moreover, it is evident that some technologies have been under development for many years and have been improved considerably during that time.

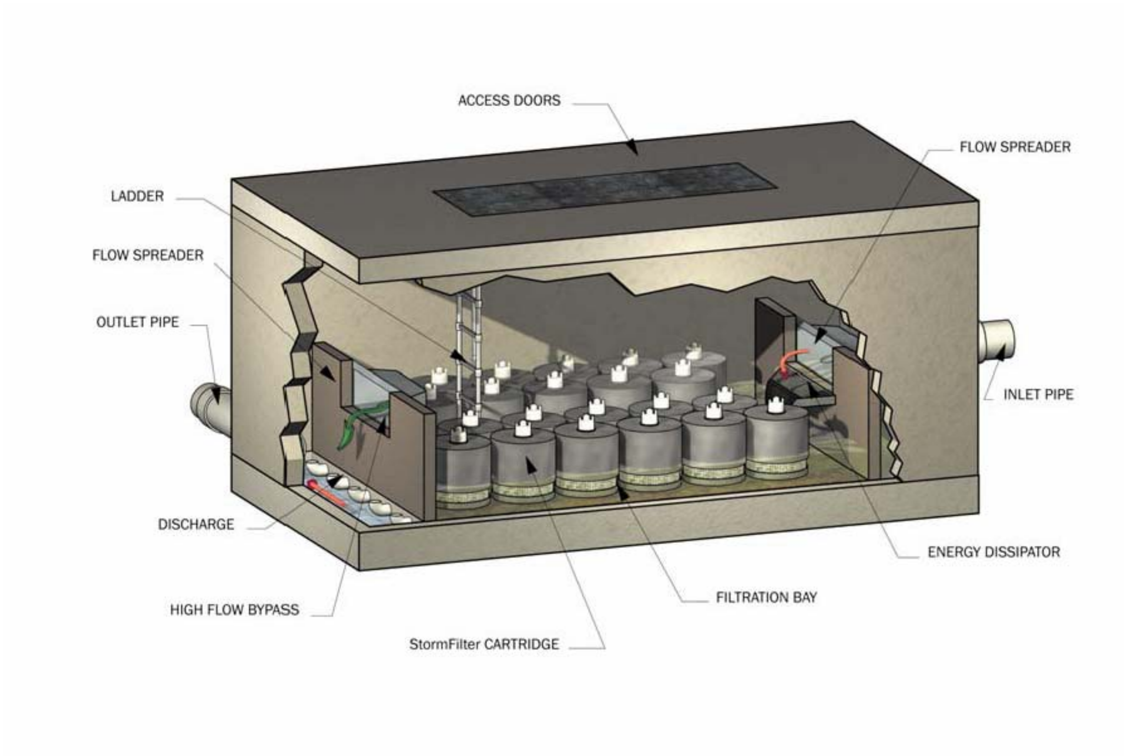
To assess and classify levels of developments, Ecology is proposing to use the criteria given below. These criteria will be included on the web site. Emerging technologies shall be used only within the application criteria and performance limits listed at Ecology's web site. Best professional judgment may be used in the interim until the Ecology-TRC process is operational.

- **Pilot Use Level –** This level will be designated for promising technologies that need more verification testing. Pilot studies could typically be conducted at roadway, commercial and residential sites, or specific land uses for which the system is marketed. Runoff at each site should be tested at full flow (design flow) conditions using reasonable evaluation criteria before deciding on a limited or general statewide use of the technology. The pilot studies should be conducted during dry and wet seasons.
- **General Use Level –** This level will be designated if the evaluation report demonstrates, with a sufficient degree of confidence, that the technology is expected to achieve Ecology's performance goals. To obtain general acceptance in eastern Washington, the performance criteria as specified in Section 5.1 must be met using the Ecology testing protocol or other acceptable protocol. Final application, design and O&M criteria, and costs must be determined. Approvals may include application as part of a treatment train and/or as a stand-alone BMP.
- **Conditional Short-Term Use Designation –** This designation can be issued for those technologies that are in widespread use in Washington, and that are considered likely to attain a General Use Level provided that testing following the protocol is completed within a specified time-period.

5.12.6 Examples of Emerging Technologies for Stormwater Treatment and Control

The descriptions and other supplier information provided in this section should not be construed as approvals by Ecology of any of the technologies. Suppliers of these emerging technologies are encouraged to submit performance verification data to Ecology in accordance with the Ecology-TRC process described earlier in this section.

Figure 5.12.1 Vertical Media Filter



Source: Courtesy of Stormwater Management, Inc.

Media Filters

Introduction

The media filter technology has been under development in the Pacific Northwest since the early 1990s. During the early stages of development, a leaf compost medium was used in fixed beds, replacing sand. Continued development of this technology is based on placing the media in filter cartridges (vertical media filters) instead of fixed beds, and amending the media (Varner, Phyllis, City of Bellevue, 1999) with constituents that will improve effectiveness (See Figure 5.12.1). Many systems have been installed in the U.S. The primary target pollutants for removal are: TSS, total and soluble phosphorous, total nitrogen, soluble metals, and oil & grease and other organics.

Description

The media can be housed in cartridge filters enclosed in concrete vaults, or in fixed beds such as the sand filters described in Section 5.8. An assortment of filter media are available including leaf compost, pleated fabric, activated charcoal, perlite, amended sand and perlite, and zeolite. The system functions by routing the stormwater through the filtering or sorbing medium, which traps particulates and/or soluble pollutants. (Leif, Bill, 1999; Stormwater Management Company, 1999)

Performance Objectives

Media can be selected for removal of TSS, oil/grease or total petroleum hydrocarbons, soluble metals, nutrients and organics. (See Section 4 for performance objectives.)

Applications and limitations

Typical applications and limitations include:

- Pretreatment is required for high TSS and/or hydrocarbon loadings and debris that could cause premature failures due to clogging
- Media filtration, such as amended sand, (Varner, Phyllis, City of Bellevue, 1999) should be considered for some Metals Treatment applications to remove soluble metals and soluble phosphates
- These systems may be designed as on-line systems for small drainage areas, or as off-line systems.
- For off-line applications, flows greater than the design flow shall be bypassed.

Site Suitability

Consider:

- Space requirements
- Design flow characteristics
- Target pollutants
- O & M requirements
- Capital and annual costs

Design Criteria for TSS Removal

Determine TSS loading and peak design flow.

- Determine TSS loading capacity per cartridge based on manufacturer's loading and flow design criteria to determine number and size of cartridges.
- Evaluate for pre-treatment needs. Typically, roadways, single family dwellings, and developments with steep slopes and erodible soils need pretreatment for TSS. Developments producing sustained oil and grease loads should be evaluated for oil and grease pretreatment needs.
- Select media based on pollutants of concern which are typically based on land use and local agency guidelines.

Pretreatment and Bypassing

- Use source control where feasible, including gross pollutant removal, sweeping, and spill containment Maintain catchbasins as needed to minimize inlet debris that could impair the operation of the filter media.
- Sedimentation vaults/ponds/ tanks, innovative more efficient catchbasins, oil/water separators for oil > 25 ppm, or other appropriate pre-treatment system to improve and maintain the operational efficiency of the filter media
- Bypassing of flows above design flows should be included.

Construction

- A precast or cast-in-place vault is typically installed over an underdrain manifold pipe system. This is followed by installation of the cartridges.
- Prior to cartridge installation construction sites must be stabilized to prevent erosion and solids loading.

Maintenance

- Follow manufacturers O & M guidelines to maintain design flows and pollutant removals.
- Based on TSS loading and cartridge capacity calculate maintenance frequency Additional Applications, Limitations, Design, Construction, and Maintenance Criteria (See Ecology web site when available).

Amended Sand Filter

Description

The addition of media to improve the pollutant removal capabilities of basic sand filters.

Recent Performance Results

In a thorough study (Varner, Phyllis, City of Bellevue, 1999) of the performance of sand filters amended with processed steel fiber (95% sand and 5% processed steel fiber by volume), and crushed calcitic limestone (90% sand and 10% crushed calcitic limestone by volume), the city of Bellevue reported significant reductions in total phosphorus and dissolved zinc in runoff from the Lakemont residential area. Because the Lakemont filter study was a detailed, well-documented, and reviewed analysis of a full scale operation, Ecology considers this technology as sufficiently advanced in development to allow its use as an option under the Metals Treatment Menu and the Phosphorus Treatment Menu. Sand filters amended with one of these media should be sized using the design criteria for a basic sand filter. Ecology prefers that these amendments be tested at another location to confirm the performances achieved by the Lakemont study and to further refine the design criteria.

Catch Basin Inserts (CBI)

Introduction

CBIs have been under development for many years in the Puget Sound Basin. They function similarly to media filtration except that they are typically limited by the size of the catch basin. They also are likely to be maintenance intensive.

Description

Catch basin inserts typically consist of the following components:

- A structure (screened box, brackets, etc.) which contains a pollutant removal medium
- A means of suspending the structure in a catch basin
- A filter medium such as sand, carbon, fabric, etc.
- A primary inlet and outlet for the stormwater
- A secondary outlet for bypassing flows that exceed design flow

Applications and Limitations

By treating runoff close to its source, the volume of flow is minimized and more effective pollutant removal is therefore possible. Depending on the insert medium, removals of TSS, organics (including oils), and metals can be achieved. The main drawbacks are the limited retention capacities and maintenance requirements on the order of once per month in the wet season to clean or replace the medium. Based on two studies of catch basin inserts,(Koon, John, Interagency Catchbasin Insert Committee, 1995; Leif, William, Snohomish County 1998) the following are potential limitations and applications for specifically designated CBIs.

- CBIs are not recommended as a substitute for basic BMPs such as wet ponds, vaults, constructed wetlands, grass swales, sand filters or related BMPs.
- CBIs can be used as temporary sediment control devices and pretreatment at construction sites.
- CBIs can be considered for oil control at small sites where the insert medium has sufficient hydrocarbon loading capacity and rate of removal, and the TSS and debris will not prematurely clog the

insert.

- CBIs can be used in unpaved areas and should be considered equivalent to currently accepted inlet protection BMPs.
- CBIs can be used when an existing catch basin lacks a sump or has an undersized sump.
- CBIs can cause flooding when plugged.
- CBIs may be considered in specialized small drainage applications for specific target pollutants where clogging of the medium will not be a problem.

Manufactured Storm Drain Structures

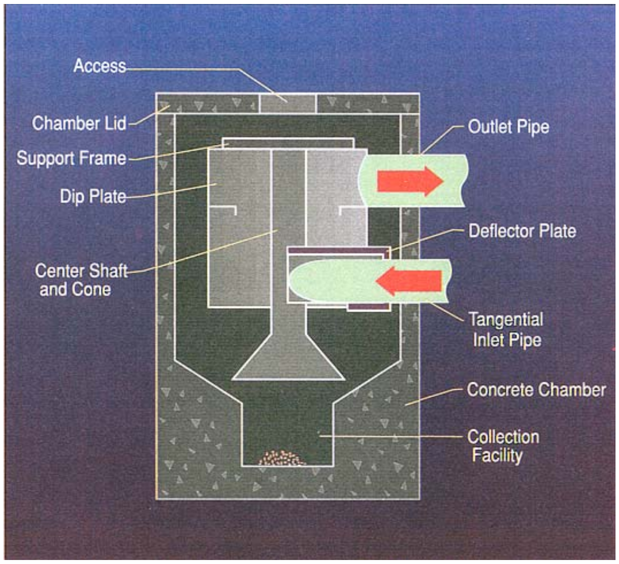
Most of these types of systems marketed thus far are cylindrical in shape and are designed to fit into or adjacent to existing storm drainage systems or catch basins. The removal mechanisms include vortex-enhanced sedimentation, circular screening, and engineered designs of internal components, for large particle TSS and large oil droplets.

<u>Vortex-enhanced Sedimentation</u>

Description: Vortex-enhanced sedimentation consists of a cylindrical vessel with tangential inlet flow which spirals down the perimeter, thus causing the heavier particles to settle. It uses a vortex-enhanced settling mechanism (swirl-concentration) to capture settleable solids, floatables, and oil and grease. This system includes a wall to separate TSS from oil. See Figure 5.12.2.

Applications, Limitations, Design, Construction, and Maintenance Criteria: See Ecology website when available.

Figure 5.12.2 Vortex-enhanced settling mechanism

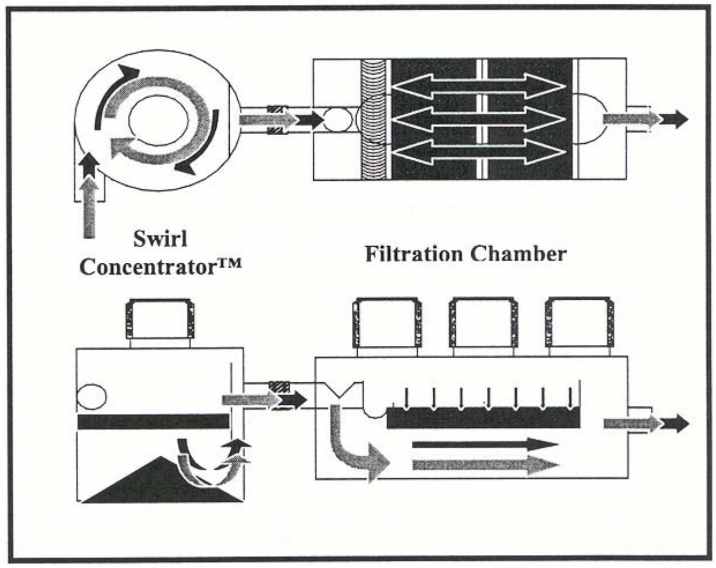


Source: courtesy of HIL, Inc.

<u>Vortex-enhanced Sedimentation and Media Filtration</u>

Description This system uses a two-stage approach which includes a swirl concentrator followed by a filtration chamber. See Figure 5.12.3.

Figure 5.12.3   Vortex-enhanced Sedimentation and Media Filtration

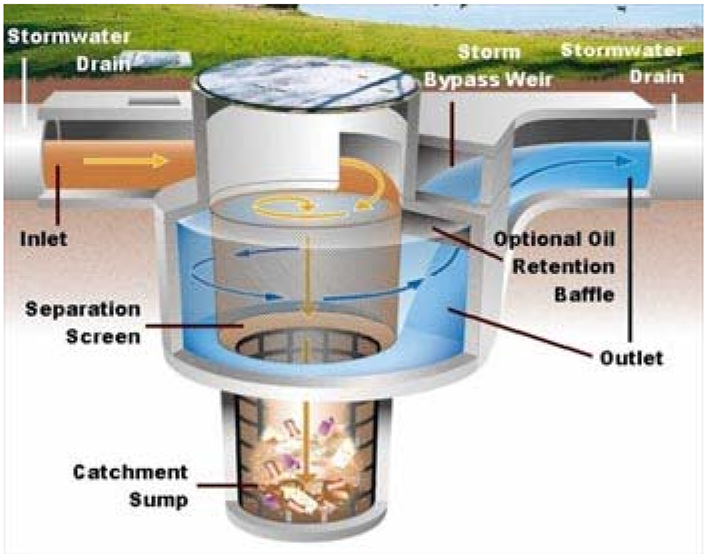


Source: courtesy of Aquafilter, Inc.

Cylindrical Screening System

Description: This system is comprised of a cylindrical screen and appropriate baffles and inlet/outlet structures to remove debris, large particle TSS, and large oil droplets. It includes an overflow for flows exceeding the design flow. Sorbents can be added to the separation chamber to increase pollutant removal efficiency. See Figure 5.12.4.

Figure 5.12.4 Screen Separator



Source: courtesy of CDS Technologies, Inc.

Engineered Cylindrical Sedimentation

Description: This system is comprised of an engineered internal baffle arrangement and oil/TSS storage compartment designed to provide considerably better removals of large particle TSS and oil droplets than the standard catch basins. It includes a bypass of flows higher than design flows, thus preventing scouring of collected solids and oils during the bigger storms.

5.12.7 High Efficiency Street Sweepers

Description

A new generation of street sweepers has been developed that utilize strong vacuums to pick up small particulates. They include mechanical sweeping and air filtration to control air emissions to acceptable levels. At least two manufacturers market what is referred to as a "high-efficiency" street sweeper.

Application

High-efficiency street sweepers are being marketed for roadways that are sufficiently accessible, need fine particulate removal (<250 microns), and for which a sufficient frequency of sweeping can be maintained to achieve proper removals of street dirt.

Limitations

- Limited field data and dependence on modeling projections.
- May not be sufficiently effective during wet conditions.
- More expensive than traditional sweepers - the cost of alternative BMPs should be compared.
- Increased storm frequency, with short intervals between storms, results in a need for increased frequency of sweeping.
- May depend on its availability, particularly during the wet season, and the need for a minimum in-place backup treatment facility.

Appendix 5A – Recommended Maintenance Criteria

The facility-specific maintenance standards contained in this section are intended to be conditions for determining if maintenance actions are required as identified through inspection. They are not intended to be measures of the facility's required condition at all times between inspections. In other words, exceedance of these conditions at any time between inspections and/or maintenance does not automatically constitute a violation of these standards. However, based upon inspection observations, the inspection and maintenance schedules shall be adjusted to minimize the length of time that a facility is in a condition that requires a maintenance action.

No. 1 – Wetponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	Any trash and debris which exceed 5 cubic feet per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size garbage can). In general, there should be no visual evidence of dumping. If less than threshold, all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site.
	Poisonous Vegetation and Noxious Weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined by state or local regulations. (Apply requirements of adopted IPM policies for the use of herbicides).	No danger of poisonous vegetation where maintenance personnel or the public might normally be. (Coordinate with local health department) Complete eradication of noxious weeds may not be possible. Compliance with state or local eradication policies required.
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants (Coordinate removal/cleanup with local water quality response agency).	No contaminants or pollutants present.
	Rodent Holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents destroyed and dam or berm repaired. (Coordinate with local health department; coordinate with Ecology Dam Safety Office if pond exceeds 10 acre-feet.)

No. 1 – Wetponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
	Beaver Dams	Dam results in change or function of the facility.	Facility is returned to design function. (Coordinate trapping of beavers and removal of dams with appropriate permitting agencies.)
	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site. Apply insecticides in compliance with adopted IPM policies.
	Tree Growth and Hazard Trees	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove. If dead, diseased, or dying trees are identified. (Use a certified Arborist to determine health of tree or removal requirements.)	Trees do not hinder maintenance activities. Harvested trees should be recycled into mulch or other beneficial uses (e.g., alders for firewood). Remove hazard trees.
Side Slopes of Pond	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes should be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. If erosion is occurring on compacted berms, a licensed civil engineer should be consulted to resolve source of erosion.
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the facility.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (If Applicable)	Liner is visible and has more than three 1/4-inch holes in it.	Liner repaired or replaced. Liner is fully covered.

No. 1 – Wetponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed civil engineer should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.)	Piping eliminated. Erosion potential resolved.
Emergency Overflow/ Spillway and Berms over 4 feet in height.	Tree Growth	Tree growth on emergency spillways creates blockage problems and may cause failure of the berm due to uncontrolled overtopping. Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees should be removed. If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A licensed civil engineer should be consulted for proper berm/spillway restoration.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.)	Piping eliminated. Erosion potential resolved.

No. 1 – Wetponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Emergency Overflow/ Spillway	Emergency Overflow/ Spillway	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil at the top of out flow path of spillway. (Rip-rap on inside slopes need not be replaced.)	Rocks and pad depth are restored to design standards.
General	Water level	First cell is empty, doesn't hold water.	Line the first cell to maintain at least 4 feet of water. Although the second cell may drain, the first cell must remain full to control turbulence of the incoming flow and reduce sediment resuspension.
	Trash and Debris	Accumulation that exceeds 1 CF per 1000-SF of pond area.	Trash and debris removed from pond.
	Inlet/Outlet Pipe	Inlet/Outlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Sediment Accumulation in Pond Bottom	Sediment accumulations in pond bottom that exceeds the depth of sediment zone plus 6-inches, usually in the first cell.	Sediment removed from pond bottom.
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.
	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom, that exceeds 6-inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
	Settlement of Pond Dike/Berm	Any part of these components that has settled 4-inches or lower than the design elevation, or inspector determines dike/berm is unsound.	Dike/berm is repaired to specifications.
	Internal Berm	Berm dividing cells should be level.	Berm surface is leveled so that water flows evenly over entire length of berm.
	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks replaced to specifications.

No. 2 – Bio-infiltration/Infiltration Trenches/Basins

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	See "Wetponds" (No. 1).	See "Wetponds" (No. 1).
	Poisonous/Noxious Vegetation	See "Wetponds" (No. 1).	See "Wetponds" (No. 1).
	Contaminants and Pollution	See "Wetponds" (No. 1).	See "Wetponds" (No. 1).
	Rodent Holes	See "Wetponds" (No. 1).	See "Wetponds" (No. 1).
Storage Area	Sediment	Water ponding in infiltration pond after rainfall ceases and appropriate time allowed for infiltration. (A percolation test pit or test of facility indicates facility is only working at 90% of its designed capabilities. If two inches or more sediment is present, remove).	Sediment is removed and/or facility is cleaned so that infiltration system works according to design.
Rock Filters	Sediment and Debris	By visual inspection, little or no water flows through filter during heavy rain storms.	Gravel in rock filter is replaced.
Side Slopes of Pond	Erosion	See "Wetponds" (No. 1).	See "Wetponds" (No. 1).
Emergency Overflow Spillway and Berms over 4 feet in height.	Tree Growth	See "Wetponds" (No. 1).	See "Wetponds" (No. 1).
	Piping	See "Wetponds" (No. 1).	See "Wetponds" (No. 1).
Emergency Overflow Spillway	Rock Missing	See "Wetponds" (No. 1).	See "Wetponds" (No. 1).
	Erosion	See "Wetponds" (No. 1).	See "Wetponds" (No. 1).
Pre-Settling Ponds and Vaults	Facility or sump filled with Sediment and/or debris	6" or designed sediment trap depth of sediment.	Sediment is removed.

No. 3 – Closed Treatment Systems (Tanks/Vaults)

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Storage Area	Plugged Air Vents	One-half of the cross section of a vent is blocked at any point or the vent is damaged.	Vents open and functioning.
	Debris and Sediment	Accumulated sediment depth exceeds 10% of the diameter of the storage area for 1/2 length of storage vault or any point depth exceeds 15% of diameter. (Example: 72-inch storage tank would require cleaning when sediment reaches depth of 7 inches for more than 1/2 length of tank.)	All sediment and debris removed from storage area.
	Joints Between Tank/Pipe Section	Any openings or voids allowing material to be transported into facility. (Will require engineering analysis to determine structural stability).	All joint between tank/pipe sections are sealed.
	Tank Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape. (Review required by engineer to determine structural stability).	Tank/pipe repaired or replaced to design.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls.	No cracks more than 1/4-inch wide at the joint of the inlet/outlet pipe.
Manhole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread (may not apply to self-locking lids).	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.
Catch Basins	See “Catch Basins” (No. 5)	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 4 – Control Structure/Flow Restrictor for Wetponds

Maintenance Component	**Defect**	**Condition When Maintenance is Needed**	**Results Expected When Maintenance is Performed**
General	Trash and Debris (Includes Sediment)	Material exceeds 25% of sump depth or 1 foot below orifice plate.	Control structure orifice is not blocked. All trash and debris removed.
	Structural Damage	Structure is not securely attached to manhole wall.	Structure securely attached to wall and outlet pipe.
		Structure is not in upright position (allow up to 10% from plumb).	Structure in correct position.
		Connections to outlet pipe are not watertight and show signs of rust.	Connections to outlet pipe are water tight; structure repaired or replaced and works as designed.
		Any holes--other than designed holes--in the structure.	Structure has no holes other than designed holes.
Cleanout Gate	Damaged or Missing	Cleanout gate is not watertight or is missing.	Gate is watertight and works as designed.
		Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.
		Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
		Gate is rusted over 50% of its surface area.	Gate is repaired or replaced to meet design standards.
Orifice Plate	Damaged or Missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow Pipe	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.
Manhole	See "Closed Treatment Systems" (No. 3).	See "Closed Treatment Systems" (No. 3).	See "Closed Treatment Systems" (No. 3).
Catch Basin	See "Catch Basins" (No. 5).	See "Catch Basins" (No. 5).	See "Catch Basins" (No. 5).

No. 5 – Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
General	Trash & Debris	Trash or debris which is located immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%.	No Trash or debris located immediately in front of catch basin or on grate opening.
		Trash or debris (in the basin) that exceeds 60% of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the debris surface to the invert of the lowest pipe.	No trash or debris in the catch basin.
		Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height.	Inlet and outlet pipes free of trash or debris.
		Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation present within the catch basin.
	Sediment	Sediment (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe.	No sediment in the catch basin
	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch (Intent is to make sure no material is running into basin).	Top slab is free of holes and cracks.
		Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached	Frame is sitting flush on the riser rings or top slab and firmly attached.
	Fractures or Cracks in Basin Walls/ Bottom	Maintenance person judges that structure is unsound.	Basin replaced or repaired to design standards.
		Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks.	Pipe is regrouted and secure at basin wall.
	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.	Basin replaced or repaired to design standards.
	Vegetation	Vegetation growing across and blocking more than 10% of the basin opening.	No vegetation blocking opening to basin.
		Vegetation growing in inlet/outlet pipe joints that is more than six inches tall and less than six inches apart.	No vegetation or root growth present.

No. 5 – Catch Basins

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is performed
	Contamination and Pollution	See "Wetponds" (No. 1).	No pollution present.
Catch Basin Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Catch basin cover is closed
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread.	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is keep cover from sealing off access to maintenance.)	Cover can be removed by one maintenance person.
Ladder	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Metal Grates (If Applicable)	Grate opening Unsafe	Grate with opening wider than 7/8 inch.	Grate opening meets design standards.
	Trash and Debris	Trash and debris that is blocking more than 20% of grate surface inletting capacity.	Grate free of trash and debris.
	Damaged or Missing.	Grate missing or broken member(s) of the grate.	Grate is in place and meets design standards.

No. 6 – Debris Barriers (e.g., Trash Racks)

Maintenance Components	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris	Trash or debris that is plugging more than 20% of the openings in the barrier.	Barrier cleared to design flow capacity.
Metal	Damaged/ Missing Bars.	Bars are bent out of shape more than 3 inches.	Bars in place with no bends more than 3/4 inch.
		Bars are missing or entire barrier missing.	Bars in place according to design.
		Bars are loose and rust is causing 50% deterioration to any part of barrier.	Barrier replaced or repaired to design standards.
	Inlet/Outlet Pipe	Debris barrier missing or not attached to pipe	Barrier firmly attached to pipe

No. 7 – Energy Dissipators

Maintenance Components	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
External:			
Rock Pad	Missing or Moved Rock	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil.	Rock pad replaced to design standards.
	Erosion	Soil erosion in or adjacent to rock pad.	Rock pad replaced to design standards.
Dispersion Trench	Pipe Plugged with Sediment	Accumulated sediment that exceeds 20% of the design depth.	Pipe cleaned/flushed so that it matches design.
	Not Discharging Water Properly	Visual evidence of water discharging at concentrated points along trench (normal condition is a “sheet flow” of water along trench). Intent is to prevent erosion damage.	Trench redesigned or rebuilt to standards.
	Perforations Plugged.	Over 1/2 of perforations in pipe are plugged with debris and sediment.	Perforated pipe cleaned or replaced.
	Water Flows Out Top of “Distributor” Catch Basin.	Maintenance person observes or receives credible report of water flowing out during any storm less than the design storm or is causing or appears likely to cause damage.	Facility rebuilt or redesigned to standards.
	Receiving Area Over-Saturated	Water in receiving area is causing or has potential of causing landslide problems.	No danger of landslides.
Internal:			
Manhole/Chamber	Worn or Damaged Post, Baffles, Side of Chamber	Structure dissipating flow deteriorates to 1/2 of original size or any concentrated worn spot exceeding one square foot which would make structure unsound.	Structure replaced to design standards.
	Other Defects	See “Catch Basins” (No. 5).	See “Catch Basins” (No. 5).

No. 8 – Biofiltration Swale

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits on grass treatment area of the bio-swale. When finished, swale should be level from side to side and drain freely toward outlet. There should be no areas of standing water once inflow has ceased.
	Standing Water	When water stands in the swale between storms and does not drain freely.	Any of the following may apply: remove sediment or trash blockages, improve grade from head to foot of swale, remove clogged check dams, add underdrains or convert to a wet biofiltration swale.
	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire swale width.	Level the spreader and clean so that flows are spread evenly over entire swale width.
	Constant Baseflow	When small quantities of water continually flow through the swale, even when it has been dry for weeks, and an eroded, muddy channel has formed in the swale bottom.	Add a low-flow pea-gravel drain the length of the swale or by-pass the baseflow around the swale.
	Poor Vegetation Coverage	When grass is sparse or bare or eroded patches occur in more than 10% of the swale bottom.	Determine why grass growth is poor and correct that condition. Re-plant with plugs of grass from the upper slope: plant in the swale bottom at 8-inch intervals. Or re-seed into loosened, fertile soil.
	Vegetation	When the grass becomes excessively tall (greater than 10 inches); when nuisance weeds and other vegetation start to take over.	Mow vegetation or remove nuisance vegetation so that flow not impeded. Grass should be mowed to a height of 3 to 4 inches. Remove grass clippings.
	Excessive Shading	Grass growth is poor because sunlight does not reach swale.	If possible, trim back over-hanging limbs and remove brushy vegetation on adjacent slopes.
	Inlet/Outlet	Inlet/outlet areas clogged with sediment and/or debris.	Remove material so that there is no clogging or blockage in the inlet and outlet area.
	Trash and Debris Accumulation	Trash and debris accumulated in the bio-swale.	Remove trash and debris from bioswale.
	Erosion/Scouring	Eroded or scoured swale bottom due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. If bare areas are large, generally greater than 12 inches wide, the swale should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident, or take plugs of grass from the upper slope and plant in the swale bottom at 8-inch intervals.

No. 9 – Vegetated Filter Strip

Maintenance Component	Defect or Problem	Condition When Maintenance is Needed	Recommended Maintenance to Correct Problem
General	Sediment Accumulation on Grass	Sediment depth exceeds 2 inches.	Remove sediment deposits, re-level so slope is even and flows pass evenly through strip.
	Vegetation	When the grass becomes excessively tall (greater than 10-inches); when nuisance weeds and other vegetation starts to take over.	Mow grass, control nuisance vegetation, such that flow not impeded. Grass should be mowed to a height between 3-4 inches.
	Trash and Debris Accumulation	Trash and debris accumulated on the filter strip.	Remove trash and debris from filter.
	Erosion/Scouring	Eroded or scoured areas due to flow channelization, or higher flows.	For ruts or bare areas less than 12 inches wide, repair the damaged area by filling with crushed gravel. The grass will creep in over the rock in time. If bare areas are large, generally greater than 12 inches wide, the filter strip should be re-graded and re-seeded. For smaller bare areas, overseed when bare spots are evident.
	Flow spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed through entire filter width.	Level the spreader and clean so that flows are spread evenly over entire filter width.

No. 10 – Wetvaults

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash/Debris Accumulation	Trash and debris accumulated in vault, pipe or inlet/outlet (includes floatables and non-floatables).	Remove trash and debris from vault.
	Sediment Accumulation in Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6-inches.	Remove sediment from vault.
	Damaged Pipes	Inlet/outlet piping damaged or broken and in need of repair.	Pipe repaired or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened or removed, especially by one person.	Pipe repaired or replaced to proper working specifications.
	Ventilation	Ventilation area blocked or plugged.	Blocking material removed or cleared from ventilation area. A specified % of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	Maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection staff.	Baffles repaired or replaced to specifications.
	Access Ladder Damage	Ladder is corroded or deteriorated, not functioning properly, not attached to structure wall, missing rungs, has cracks and/or misaligned. Confined space warning sign missing.	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel. Replace sign warning of confined space entry requirements. Ladder and entry notification complies with OSHA standards.

No. 11 – Sand Filters (above-ground/open)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Above-Ground (open sand filter)	Sediment Accumulation on top layer	Sediment depth exceeds 1/2-inch.	No sediment deposit on grass layer of sand filter that would impede permeability of the filter section.
	Trash and Debris Accumulations	Trash and debris accumulated on sand filter bed.	Trash and debris removed from sand filter bed.
	Sediment/ Debris in Clean-Outs	When the clean-outs become full or partially plugged with sediment and/or debris.	Sediment removed from clean-outs.
	Sand Filter Media	Drawdown of water through the sand filter media takes longer than 24-hours, and/or flow through the overflow pipes occurs frequently.	Top several inches of sand are scraped. May require replacement of entire sand filter depth depending on extent of plugging (a sieve analysis is helpful to determine if the lower sand has too high a proportion of fine material).
	Prolonged Flows	Sand is saturated for prolonged periods of time (several weeks) and does not dry out between storms due to continuous base flow or prolonged flows from detention facilities.	Low, continuous flows are limited to a small portion of the facility by using a low wooden divider or slightly depressed sand surface.
	Short Circuiting	When flows become concentrated over one section of the sand filter rather than dispersed.	Flow and percolation of water through sand filter is uniform and dispersed across the entire filter area.
	Erosion Damage to Slopes	Erosion over 2-inches deep where cause of damage is prevalent or potential for continued erosion is evident.	Slopes stabilized using proper erosion control measures.
	Rock Pad Missing or Out of Place	Soil beneath the rock is visible.	Rock pad replaced or rebuilt to design specifications.
	Flow Spreader	Flow spreader uneven or clogged so that flows are not uniformly distributed across sand filter.	Spreader leveled and cleaned so that flows are spread evenly over sand filter.
	Damaged Pipes	Any part of the piping that is crushed or deformed more than 20% or any other failure to the piping.	Pipe repaired or replaced.

No. 12 –Sand Filters (below-ground/enclosed)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below -Ground Vault.	Sediment Accumulation on Sand Media Section	Sediment depth exceeds 1/2-inch.	No sediment deposits on sand filter section that which would impede permeability of the filter section.
	Sediment Accumulation in Pre-Settling Portion of Vault	Sediment accumulation in vault bottom exceeds the depth of the sediment zone plus 6 inches.	No sediment deposits in first chamber of vault.
	Trash/Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
	Sediment in Drain Pipes/Cleanouts	When drain pipes, cleanouts become full with sediment and/or debris.	Sediment and debris removed.
	Short Circuiting	When seepage/flow occurs along the vault walls and corners. Sand eroding near inflow area.	Sand filter media section re-laid and compacted along perimeter of vault to form a semi-seal. Erosion protection added to dissipate force of incoming flow and curtail erosion.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover. Maintenance person cannot remove cover using normal lifting pressure.	Cover repaired to proper working specifications or replaced.
	Ventilation	Ventilation area blocked or plugged	Blocking material removed or cleared from ventilation area. A specified % of the vault surface area must provide ventilation to the vault interior (see design specifications).
	Vault Structure Damaged; Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab.	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles/Internal walls	Baffles or walls corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.

No. 12 –Sand Filters (below-ground/enclosed)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired to specifications, and is safe to use as determined by inspection personnel.

No. 13 – Media Filter

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Below-Ground Vault	Sediment Accumulation on Media.	Sediment depth exceeds 0.25-inches.	No sediment deposits which would impede permeability of the media.
	Sediment Accumulation in Vault	Sediment depth exceeds 6 inches in first chamber.	No sediment deposits in vault bottom of first chamber.
	Trash/Debris Accumulation	Trash and debris accumulated on filter bed.	Trash and debris removed from the filter bed.
	Sediment in Drain Pipes/Clean-Outs	When drain pipes, clean-outs, become full with sediment and/or debris.	Sediment and debris removed.
	Damaged Pipes	Any part of the pipes that are crushed or damaged due to corrosion and/or settlement.	Pipe repaired and/or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened; one person cannot open the cover using normal lifting pressure, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking warping, and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.
Below-Ground Cartridge Type	Filter Media	Drawdown of water through the media takes longer than 1 hour, and/or overflow occurs frequently.	Media cartridges replaced.
	Short Circuiting	Flows do not properly enter filter cartridges.	Filter cartridges replaced.

No. 14 – Baffle Oil/Water Separators (API Type)

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear with out thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6 inches in depth.	No sediment deposits on vault bottom that would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulation in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault, and inlet/outlet piping.
	Oil Accumulation	Oil accumulations that exceed 1 inch, at the surface of the water.	Extract oil from vault by vactoring. Disposal in accordance with state and local rules and regulations.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired or replaced.
	Access Cover Damaged/Not Working	Cover cannot be opened, corrosion/deformation of cover.	Cover repaired to proper working specifications or replaced.
	Vault Structure Damage - Includes Cracks in Walls Bottom, Damage to Frame and/or Top Slab	See “Catch Basins” (No. 5)	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

No. 15 – Coalescing Plate Oil/Water Separators

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Monitoring	Inspection of discharge water for obvious signs of poor water quality.	Effluent discharge from vault should be clear with no thick visible sheen.
	Sediment Accumulation	Sediment depth in bottom of vault exceeds 6 inches in depth and/or visible signs of sediment on plates.	No sediment deposits on vault bottom and plate media, which would impede flow through the vault and reduce separation efficiency.
	Trash and Debris Accumulation	Trash and debris accumulated in vault, or pipe inlet/outlet, floatables and non-floatables.	Trash and debris removed from vault and inlet/outlet piping.
	Oil Accumulation	Oil accumulation that exceeds 1 inch at the water surface.	Oil is extracted from vault using vactoring methods. Coalescing plates are cleaned by thoroughly rinsing and flushing. Should be no visible oil depth on water.
	Damaged Coalescing Plates	Plate media broken, deformed, cracked and/or showing signs of failure.	A portion of the media pack or the entire plate pack is replaced depending on severity of failure.
	Damaged Pipes	Inlet or outlet piping damaged or broken and in need of repair.	Pipe repaired and or replaced.
	Baffles	Baffles corroding, cracking, warping and/or showing signs of failure as determined by maintenance/inspection person.	Baffles repaired or replaced to specifications.
	Vault Structure Damage - Includes Cracks in Walls, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch or evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determine that the vault is not structurally sound.	Vault replaced or repairs made so that vault meets design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or evidence of soil particles entering through the cracks.	Vault repaired so that no cracks exist wider than 1/4-inch at the joint of the inlet/outlet pipe.
	Access Ladder Damaged	Ladder is corroded or deteriorated, not functioning properly, not securely attached to structure wall, missing rungs, cracks, and misaligned.	Ladder replaced or repaired and meets specifications, and is safe to use as determined by inspection personnel.

No. 16 – Catch Basin Inserts

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Sediment Accumulation	When sediment forms a cap over the insert media of the insert and/or unit.	No sediment cap on the insert media and its unit.
	Trash and Debris Accumulation	Trash and debris accumulates on insert unit creating a blockage/restriction.	Trash and debris removed from insert unit. Runoff freely flows into catch basin.
	Media Insert Not Removing Oil	Effluent water from media insert has a visible sheen.	Effluent water from media insert is free of oils and has no visible sheen.
	Media Insert Water Saturated	Catch basin insert is saturated with water and no longer has the capacity to absorb.	Remove and replace media insert
	Media Insert-Oil Saturated	Media oil saturated due to petroleum spill that drains into catch basin.	Remove and replace media insert.
	Media Insert Use Beyond Normal Product Life	Media has been used beyond the typical average life of media insert product.	Remove and replace media at regular intervals, depending on insert product.

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Chapter 6 - Flow Control Facility Design

6.1 Introduction

This chapter of the stormwater manual focuses on techniques and BMPs related to implementation of Core Element #6 – Flow Control. This chapter presents methods, criteria, and details for hydraulic analysis and design of flow control facilities. Flow control facilities are detention, infiltration, or evaporation facilities engineered to meet the flow control standards specified by the regulatory agency.

The design criteria outlined in this chapter are applicable only to those infiltration facilities used for runoff quantity control. Design criteria for infiltration facilities used for runoff quality treatment are listed in Chapter 5.

Design considerations for conveyance systems are not included in the stormwater manual, as this topic is adequately covered in standard engineering references.

In the general design of flow control facilities, the optimal placement of multiple small-scale retention/infiltration facilities within a drainage area may require less total storage capacity to meet a given peak flow rate target than a single large facility at the drainage outlet. Application of low impact development (LID) techniques may also result in decreased storage requirements; see the discussion in Chapter 2.2.6, Supplemental Guidelines.

6.2 Detention Facilities

This section presents the methods, criteria, and details for design and analysis of detention facilities. These facilities provide for the temporary storage of increased surface water runoff resulting from development pursuant to the performance standards set forth by the regulatory agency.

There are three primary types of detention facilities described in this section: detention ponds, tanks, and vaults.

6.2.1 Detention Ponds, Tanks, and Vaults

BMP F6.10 Detention Ponds

The design criteria in this section are for detention ponds. However, many of the criteria also apply to infiltration ponds (Section 6.3 and Chapter 5 – Runoff Treatment Facility Design). Detention ponds are *not* subject to UIC regulations (see Chapter 5.6).

Dam Safety for Detention BMPs

Very large stormwater detention facilities that can impound 10 acre-feet (435,600 cubic feet; 3.26 million gallons) or more with the water level at the embankment crest are subject to the state’s dam safety requirements, even if water storage is intermittent and infrequent (WAC 173-175-

020(1)). The principal safety concern is for the downstream population at risk if the dam should breach and allow an uncontrolled release of the pond contents. Peak flows from dam failures are typically much larger than the 100-year flows which these ponds are typically designed to accommodate.

Dam safety considerations generally apply only to the volume of water stored above natural ground level. Per the definition of dam height in WAC 173-175-030, natural ground elevation is measured from the downstream toe of the dam. If a trench is cut through natural ground to install an outlet pipe for a spillway or low-level drain, the natural ground elevation is measured from the base of the trench where the natural ground remains undisturbed.

The Dam Safety Office in the Department of Ecology is available to provide written guidance documents and technical assistance to project owners and design engineers in understanding and addressing the dam safety requirements for their specific project. If the pond will meet the size or depth criteria for dam safety it is requested that Dam Safety be contacted early in the facilities planning process.

Electronic versions of the guidance documents in PDF format are available on the Department of Ecology Web site at http://www.ecy.wa.gov/programs/wr/dams/dss.html.

Design Criteria

Detention ponds must meet the requirements of Core Element #6 Flow Control (see Chapter 2.6.6), particularly the release rates, and any additional requirements established by the permitting agency or local jurisdiction. To protect stream habitat, the 2-year runoff volume for the proposed development conditions must be released at a rate that does not exceed 50% of the pre-developed or existing 2-year peak flow rate. The facility should also match the 25-year peak flow rate for pre-developed or existing conditions; or it may match flow rate(s) for a different or additional recurrence interval(s) established by the permitting agency or local jurisdiction. For hydrologic analysis methods to determine these flow rates, see Chapter 4.

Standard details for detention ponds are shown in Figure 6.2.1 through Figure 6.2.3. Control structure details are provided in Section 6.2.4.

General

Ponds may be designed as flow-through systems (however, parking lot storage may be utilized through a back-up system; see Section 6.2.5). Developed flows must enter through a conveyance system separate from the control structure and outflow conveyance system. Maximizing distance between the inlet and outlet is encouraged to promote sedimentation.

Pond bottoms should be level and be located a minimum of 0.5 foot (preferably 1 foot) below the inlet and outlet to provide sediment storage.

The design professional should carefully consider and evaluate any situation where a pond will be situated upslope from a structure or behind the top of a slope inclined in excess of 15 percent. Check local critical area ordinances for unstable slopes. The minimum setback from such a slope is greater than or equal to the height of the slope, unless the design professional can justify a lesser setback based on a comprehensive site evaluation.

Side Slopes

Interior side slopes up to the emergency overflow water surface should not be steeper than 3H:1V unless a fence is provided (see “Fencing”).

Exterior side slopes should not be steeper than 2H:1V unless analyzed for stability by a geotechnical engineer.

Pond walls may be vertical retaining walls, provided: (a) they are constructed of reinforced concrete; (b) a fence is provided along the top of the wall; (c) the entire pond perimeter may be retaining walls, however, it is recommended that at least 25 percent of the pond perimeter be a vegetated soil slope not steeper than 3H:1V; and (d) the design is stamped by a licensed civil engineer with structural expertise. Other retaining walls such as rockeries, concrete, masonry unit walls, and keystone type wall may be used if designed by a geotechnical engineer or a civil engineer with structural expertise. If the entire pond perimeter is to be retaining walls, ladders should be provided on the walls for safety reasons.

Embankments

Pond berm embankments higher than 6 feet must be designed by a professional engineer with geotechnical expertise.

For berm embankments 4 feet high or less, the minimum top width should be 4 feet or as recommended by a geotechnical engineer.

Pond berm embankments must be constructed on native consolidated soil (or adequately compacted and stable fill soils analyzed by a geotechnical engineer) free of loose surface soil materials, roots, and other organic debris.

Pond berm embankments greater than 4 feet in height must be constructed by excavating a key equal to 50 percent of the berm embankment cross-sectional height and width unless specified otherwise by a geotechnical engineer.

Embankment compaction should be accomplished in such a manner as to produce a dense, low permeability engineered fill that can tolerate post-construction settlements with a minimum of cracking. The embankment fill should be placed on a stable sub-grade and compacted to a minimum of 95% of the Modified Proctor Maximum Density, ASTM Procedure D1557. Placement moisture content should lie within 1% dry to 3% wet of the optimum moisture content. The referenced degree of compaction may have to be increased to comply with local regulations.

The berm embankment should be constructed of soils with the following characteristics: a minimum of 20% silt and clay, a maximum of 60% sand, a maximum of 60% silt, with nominal gravel and cobble content. Soils outside this specified range can be used, provided the design satisfactorily addresses the engineering concerns posed by these soils. The paramount concerns with these soils are their susceptibility to internal erosion or piping and to surface erosion from wave action and runoff on the upstream and downstream slopes, respectively. Anti-seepage filter-drain diaphragms must be placed on outflow pipes in berm embankments impounding water with depths greater than 8 feet at the design water surface. See Dam Safety Guidelines at www.ecy.wa.gov/programs/wr/dams/dss.html.

Overflow

1. In all ponds, tanks, and vaults, a primary overflow (usually a riser pipe within the control structure; see Section 6.2.4) must be provided to bypass the 25-year developed peak flow over or around the restrictor system. This assumes the facility will be full due to plugged orifices or high inflows; the primary overflow is intended to protect against breaching of a pond embankment (or overflows of the upstream conveyance system in the case of a detention tank or vault). The design must provide controlled discharge directly into the downstream conveyance system or another acceptable discharge point.

2. A secondary inlet to the control structure should be provided in ponds as additional protection against overtopping should the inlet pipe to the control structure become plugged. A grated opening ("jailhouse window") in the control structure manhole functions as a weir (see Figure 6.2.2) when used as a secondary inlet.

   Note: *The maximum circumferential length of this opening must not exceed one-half the control structure circumference.* The "birdcage" overflow structure as shown in Figure 6.2.3 may also be used as a secondary inlet.

Emergency Overflow Spillway

Emergency overflow spillways are intended to control the location of pond overtopping in the event of total control structure failure (e.g., blockage of the control structure outlet pipe) or extreme inflows, and direct overflows back into the downstream conveyance system or other acceptable discharge point.

Emergency overflow spillways must be provided for ponds with constructed berms over 2 feet in height, or for ponds located on grades in excess of 5 percent. As an option for ponds with berms less than 2 feet in height and located at grades less than 5 percent, emergency overflow may be provided by an emergency overflow structure, such as a manhole fitted with a birdcage as shown in Figure 6.2.3. The emergency overflow structure must be designed to pass the 25-year developed peak flow, with a minimum 6 inches of freeboard, directly to the downstream conveyance system or another acceptable discharge point. Where an emergency overflow spillway would discharge to a steep slope, consideration should be given to providing an emergency overflow structure in addition to the spillway.

The emergency overflow spillway must be armored with riprap or other suitable material. The spillway must be armored full width, beginning at a point midway across the berm embankment and extending downstream to where emergency overflows re-enter the conveyance system (see Figure 6.2.2). Guidance for the design of the riprap can be found in HEC-11, "Design of Riprap Revetment," and HEC-14, "Hydraulic Design of Energy Dissipators for Culverts and Channels."

Emergency overflow spillway designs should be analyzed as broad-crested trapezoidal weirs.

Access

The following guidelines for access may be used.

Maintenance access road(s) should be provided to the control structure and other drainage structures associated with the pond (e.g., inlet or bypass structures). It is recommended that manhole and catch basin lids be in or at the edge of the access road and at least three feet from a property line.

An access ramp is needed for removal of sediment with a trackhoe and truck. The ramp should extend to the pond bottom if the pond bottom is greater than 1,500 square feet (measured without the ramp) and it may end at an elevation 4 feet above the pond bottom, if the pond bottom is less than 1,500 square feet (measured without the ramp).

On large, deep ponds, truck access to the pond bottom via an access ramp is necessary so loading can be done in the pond bottom. On small deep ponds, the truck can remain on the ramp for loading. On small shallow ponds, a ramp to the bottom may not be required if the trackhoe can load a truck parked at the pond edge or on the internal berm of a wetpond or combined pond (trackhoes can negotiate interior pond side slopes).

Access ramps must meet the requirements for design and construction of access roads specified below.

If a fence is required, access should be limited by a double-posted gate or by bollards – that is, two fixed bollards on each side of the access road and two removable bollards equally located between the fixed bollards.

Design of Access Roads

The design guidelines for access road are given below.

- Maximum grade should be 20 percent.
- Outside turning radius should be a minimum of 40 feet.
- Fence gates should be located only on straight sections of road.

- Access roads should be 15 feet in width on curves and 12 feet on straight sections.
- The drivable surface should have a 20-year design life to carry the load of a 24 ton truck; assume 3 trips per year.
- A paved apron must be provided where access roads connect to paved public roadways.
- A truck turn-around is required at the terminus of the road.

Construction of Access Roads

Access roads may be constructed with an asphalt or gravel surface, or modular grid pavement. All surfaces must conform to the jurisdictional standards and manufacturer's specifications.

Fencing

A fence may also be needed around impoundments of open water. Refer to the Uniform Building Code or local building codes for fencing requirements in these areas.

Right-of-Way

Right-of-way may be needed for detention pond maintenance. It is recommended that any tract not abutting public right-of-way have 15-20 foot wide extension of the tract to an acceptable access location.

Setbacks

It is recommended that the ponded area be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government. Side slopes for the pond or berm should be a minimum of 5 feet from any structure or property line. The detention pond water surface at the pond outlet invert elevation must be set back 100 feet from proposed or existing septic system drainfields. However, the setback requirements are generally specified by the local government, Uniform Building Code, or other statewide regulation, and may be different from those mentioned above.

The design professional should carefully consider and evaluate any situation where an infiltration facility will be situated upslope from a structure or behind the top of a slope inclined in excess of 15 percent. The minimum setback from such a slope is equal to ‘h’, the height of the slope, unless the design professional can justify a lesser setback based on a comprehensive site evaluation.

Seeps and Springs

Intermittent seeps along cut slopes are typically fed by a shallow groundwater source (interflow) flowing along a relatively impermeable soil stratum. These flows are storm driven and should discontinue after a few weeks of dry weather. However, more continuous seeps and springs, which extend through longer dry periods, are likely from a deeper groundwater source. When continuous flows are intercepted and directed through flow control facilities, adjustments to the facility design may have to be made to account for the additional base flow (unless already considered in design).

Planting Requirements

Exposed earth on the pond bottom and interior side slopes may be sodded or seeded with an appropriate seed mixture. All remaining areas of the tract may be planted with grass or be landscaped. See Chapter 7 Construction Stormwater Pollution Prevention for typical seed mixes.

Landscaping

If provided, landscaping should adhere to the criteria that follow so as not to hinder maintenance operations. Landscaped stormwater tracts may, in some instances, provide a recreational space. In other instances, “naturalistic” stormwater facilities may be placed in open space tracts.

The following guidelines should be followed if landscaping is proposed for facilities.

1. No trees or shrubs may be planted within 10 feet of inlet or outlet pipes or manmade drainage structures such as spillways or flow spreaders. Species with roots that seek water, such as willow or poplar, should be avoided within 50 feet of pipes or manmade structures.

2. Planting should be restricted on berms that impound water either permanently or temporarily during storms. This restriction does not apply to cut slopes that form pond banks, only to berms.

   a) Trees or shrubs may not be planted on portions of water impounding berms taller than four feet high. Only grasses may be planted on berms taller than four feet.

      Grasses allow unobstructed visibility of berm slopes for detecting potential dam safety problems such as animal burrows, slumping, or fractures in the berm.

   b) Trees planted on portions of water-impounding berms less than 4 feet high must be small, not higher than 20 feet mature height, and have a fibrous root system.

      These trees reduce the likelihood of blow-down trees, or the possibility of channeling or piping of water through the root system, which may contribute to dam failure on berms that retain water.

3. All landscape material, including grass, should be planted in good topsoil. Native underlying soils may be made suitable for planting if amended with 4 inches of well-aged compost tilled into the subgrade. Compost used should meet specifications for Grade A compost quality as described in Ecology publication 94-38.

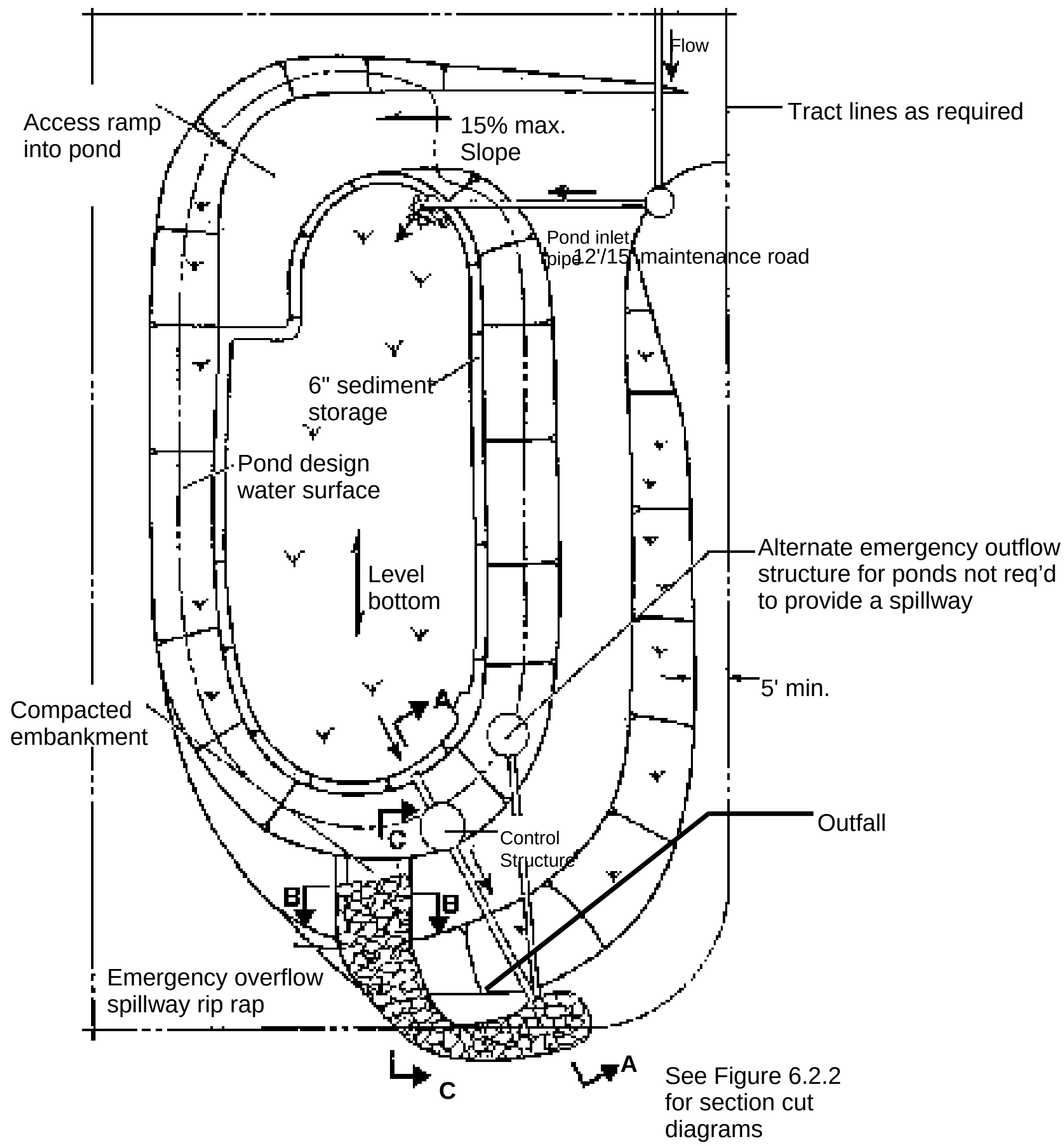
4. Soil in which trees or shrubs are planted may need additional enrichment or additional compost top-dressing. Consult a nurseryman, landscape professional, or arborist for site-specific recommendations.

5. For a naturalistic effect as well as ease of maintenance, trees or shrubs should be planted in clumps to form “landscape islands” rather than evenly spaced.

   The landscaped islands should be a minimum of six feet apart, and if set back from fences or other barriers, the setback distance should also be a minimum of 6 feet. Where tree foliage extends low to the ground, the six foot setback should be counted from the outer drip line of the trees (estimated at maturity). This setback allows a 6-foot wide mower to pass around and between clumps.

6. Evergreen trees and trees which produce relatively little leaf-fall (such as ash, locust, hawthorn) are preferred in areas draining to the pond.

7. Trees should be set back so that branches do not extend over the pond (to prevent leaf-drop into the water). Drought tolerant species are recommended.



Note:
This detail is a schematic representation only. Actual configuration will vary depending on specific site constraints and applicable design criteria.

Figure 6.2.1 – Typical detention pond

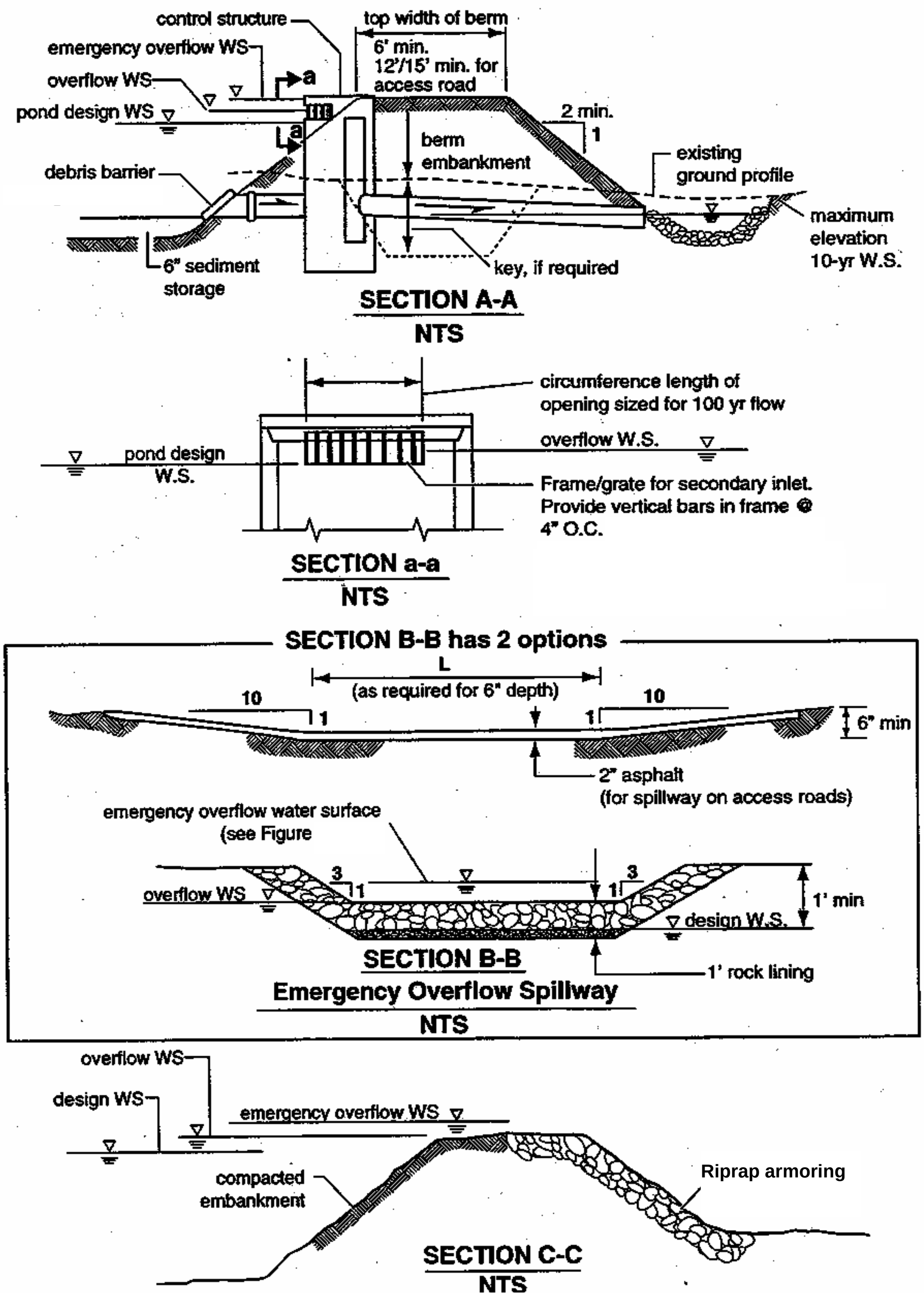
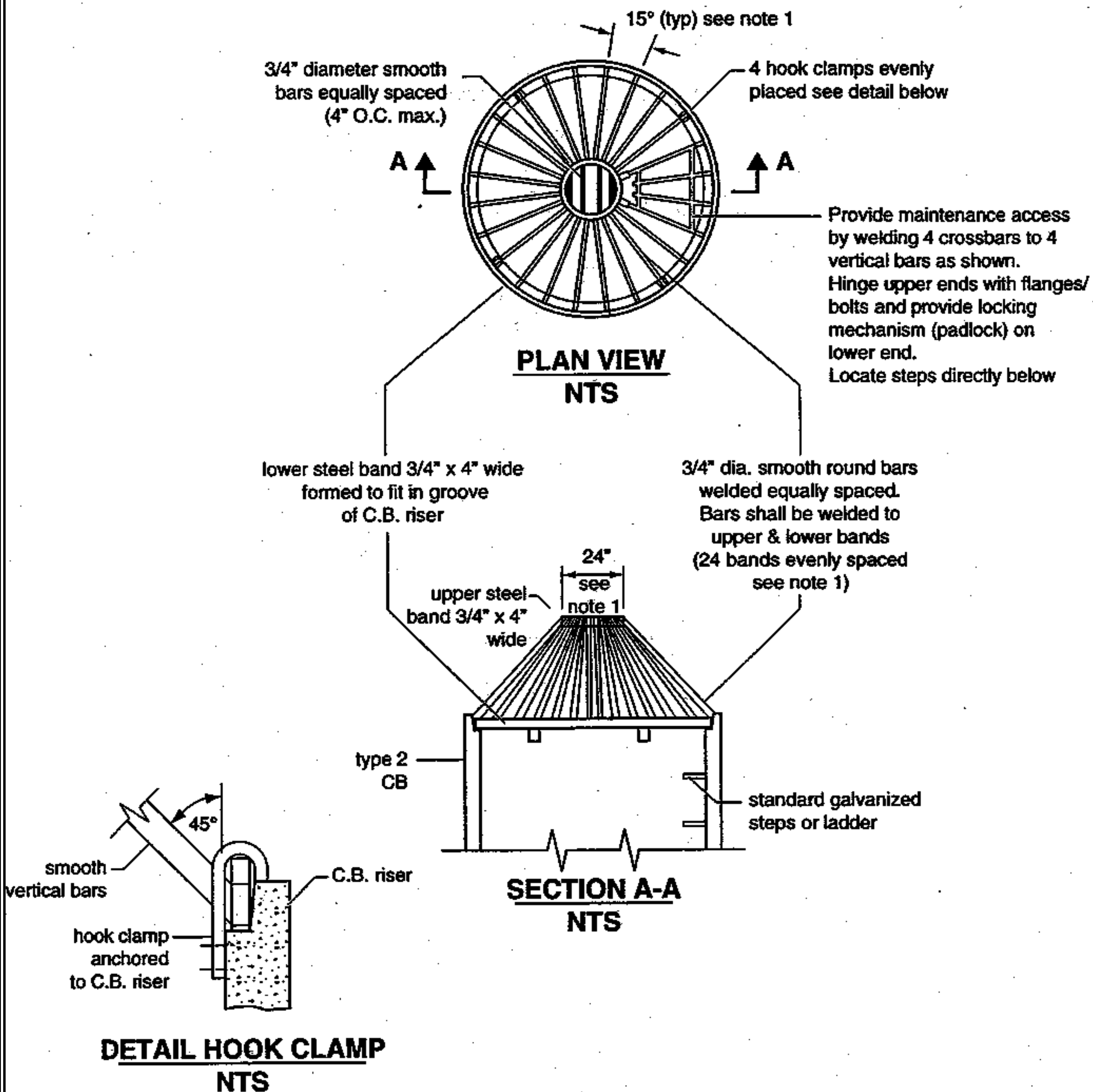


Figure 6.2.2 – Typical Detention Pond Sections



NOTES:

1. Dimensions are for illustration on 54" diameter CB For different diameter CB's adjust to maintain 45° angle on "vertical" bars and 7" o.c. maximum spacing of bars around lower steel band.
2. Metal parts must be corrosion resistant; steel bars must be galvanized.
3. This debris barrier is also recommended for use on the inlet to roadway cross-culverts with high potential for debris collection

Figure 6.2.3 – Overflow Structure

Maintenance

General. Maintenance is of primary importance if detention ponds are to continue to function as originally designed. A local government, a designated group such as a homeowners' association, or some individual should accept the responsibility for maintaining the structures and the impoundment area. A specific maintenance plan should be formulated outlining the schedule and scope of maintenance operations. Debris removal in detention basins can be achieved through the use of trash racks or other screening devices.

Design with maintenance in mind. Good maintenance will be crucial to successful use of the impoundment. Hence, provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance should be a basic consideration in design and in determination of first cost. See Appendix 6A for specific maintenance requirements.

Any standing water removed during the maintenance operation must be disposed of to a sanitary sewer at an approved discharge location. Pretreatment may be necessary. Residuals must be disposed of in accordance with state and local solid waste regulations (See Minimum Functional Standards For Solid Waste Handling, Chapter 173-304 WAC).

Vegetation. If a shallow marsh is established, then periodic removal of dead vegetation may be necessary. Since decomposing vegetation can release pollutants captured in the detention pond, especially nutrients, it may be necessary to harvest dead vegetation annually prior to the winter season. Otherwise the decaying vegetation can export pollutants out of the pond and also can cause nuisance conditions to occur.

Sediment. Maintenance of sediment forebays and attention to sediment accumulation within the pond is extremely important. Sediment deposition should be periodically monitored in the basin. Owners, operators, and maintenance authorities should be aware that significant concentrations of metals (e.g., lead, zinc, and cadmium) as well as some organics such as pesticides, may be expected to accumulate at the bottom of these treatment facilities. Testing of sediment, especially near points of inflow, should be conducted periodically to determine the leaching potential and level of accumulation of potentially hazardous material before disposal.

Methods of Analysis

Detention Volume and Outflow. The volume and outflow design for detention ponds must be in accordance with the requirements of Core Element #6, and the hydrologic analysis and design methods in Chapter 4. Design guidelines for restrictor orifice structures are given in Section 6.2.4.

Note*: The design water surface elevation is the highest elevation which occurs in order to meet the required outflow performance for the pond.*

Detention Ponds in Infiltrative Soils. Detention ponds may occasionally be sited on soils that are sufficiently permeable for a properly functioning infiltration system. These detention ponds have a surface discharge and may also utilize infiltration as a second pond outflow. Detention ponds sized with infiltration as a second outflow must meet all the requirements of Section 6.3 for infiltration ponds, including a soils report, testing, groundwater protection, pre-settling, and construction techniques.

Emergency Overflow Spillway Capacity. For impoundments under 10-acre-feet, the emergency overflow spillway weir section must be designed to pass the 25-year runoff event for developed conditions assuming a broad-crested weir. The broad-crested weir equation for the spillway section in Figure 6.2.4, for example, would be:

$$Q_{25} = C\,(2g)^{1/2}\left[\frac{2}{3}LH^{3/2} + \frac{8}{15}(\mathrm{Tan}\,\theta)\,H^{5/2}\right] \qquad \text{(Eq. 5.2.1)}$$

Where Q_{25} = peak flow for the 25-year runoff event (cfs)

C = discharge coefficient (0.6)
g = gravity (32.2 ft/sec^2)
L = length of weir (ft)
H = height of water over weir (ft)
θ = angle of side slopes

Assuming C = 0.6 and Tan θ = 3 (for 3:1 slopes), the equation becomes:

$$Q_{25} = 3.21[LH^{3/2} + 2.4\,H^{5/2}] \qquad \text{(Eq. 5.2.2)}$$

To find length L for the weir section, the equation is rearranged to use the computed Q_{25} and trial values of H (0.2 feet minimum):

$$L = [Q_{25}/(3.21H^{3/2})] - 2.4\,H \quad \text{or 6 feet minimum} \qquad \text{(Eq. 5.2.3)}$$

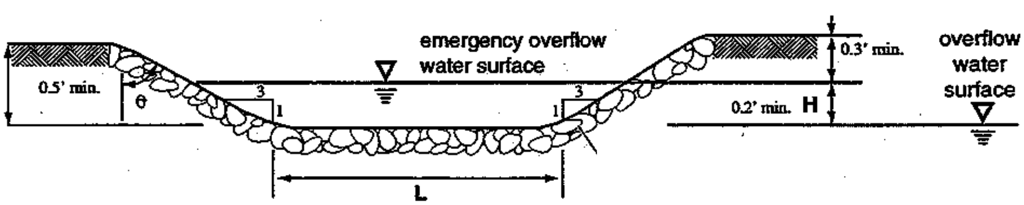


Figure 6.2.4 – Weir Section for Emergency Overflow

BMP F6.11 Detention Tanks

Detention tanks are underground storage facilities typically constructed with large diameter corrugated metal pipe. Standard detention tank details are shown in Figures 6.2.5 and 6.2.6. Control structure details are shown in Section 6.2.4. Detention tanks are not subject to UIC regulations unless the structure at the land surface is smaller than the depth of the outlet pipe *and* the pipe discharges to ground; see Chapter 5.6.

Design Criteria

General. Typical design guidelines are as follows:

1. Tanks may be designed as flow-through systems with manholes in line (see Figure 6.2.5) to promote sediment removal and facilitate maintenance. Tanks may be designed as back-up systems if preceded by water quality facilities, since little sediment should reach the inlet/control structure and low head losses can be expected because of the proximity of the inlet/control structure to the tank
2. The detention tank bottom should be located 0.5 feet below the inlet and outlet to provide dead storage for sediment.
3. The minimum pipe diameter for a detention tank is 36 inches.
4. Tanks larger than 36 inches may be connected to each adjoining structure with a short section (2-foot maximum length) of 36-inch minimum diameter pipe.

   Note: *Control and access manholes should have ladder rungs to allow ready access to all tank access pipes when the catch basin sump is filled with water*.

Materials. Pipe material, joints, and protective treatment for tanks should be in accordance with Section 9.05 of the WSDOT/APWA Standard Specification.

Structural Stability. Tanks must meet structural requirements for overburden support and traffic loading if appropriate. H-20 live loads, or other loading criteria applicable to the site, must be accommodated for tanks lying under parking areas and access roads. Metal tank end plates must be designed for structural stability at maximum hydrostatic loading conditions. Flat end plates generally require thicker gage material than the pipe and/or require reinforcing ribs. Tanks must be placed on stable, well consolidated native material with a suitable bedding. Tanks must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Buoyancy. In moderately pervious soils where seasonal groundwater may induce flotation, buoyancy tendencies must be balanced either by ballasting with backfill or concrete backfill, providing concrete anchors, increasing the total weight, or providing subsurface drains to permanently lower the groundwater table. Calculations that demonstrate stability must be documented.

Access. The following guidelines for access may be used.

1. The maximum depth from finished grade to tank invert should be 20 feet.
2. Access openings should be positioned a maximum of 50 feet from any location within the tank.

3. All tank access openings should have round, solid locking lids (usually 1/2 to 5/8-inch diameter Allen-head cap screws).
4. 36-inch minimum diameter CMP riser-type manholes (Figure 6.2.6) of the same gage as the tank material may be used for access along the length of the tank and at the upstream terminus of the tank in a backup system. The top slab is separated (1-inch minimum gap) from the top of the riser to allow for deflections from vehicle loadings without damaging the riser tank.
5. All tank access openings must be readily accessible by maintenance vehicles.
6. Tanks must comply with the OSHA confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.

Access Roads Access roads are needed to all detention tank control structures and risers. The access roads must be designed and constructed as specified for detention ponds in Section 6.2.1.

Right-of-Way. Right-of-way may be needed for detention tank maintenance. It is recommended that any tract not abutting public right-of-way have a 15 to 20-foot wide extension of the tract to accommodate an access road to the facility.

Setbacks. It is recommended that facilities be a minimum of 5 feet from any structure, property line, and any vegetative buffer required by the local government and from any septic drainfield. However, the setback requirements are generally specified by the local government, Uniform Building Code, or other statewide regulation and may be different from those mentioned above.

Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Appendix 6A for specific maintenance requirements.

Methods of Analysis

Detention Volume and Outflow. The volume and outflow design for detention tanks must be in accordance with the requirements of the regulatory agency and the hydrologic analysis and design methods in Chapter 4 - Hydrologic Analysis and Design. Restrictor and orifice design are given in Section 6.2.4.

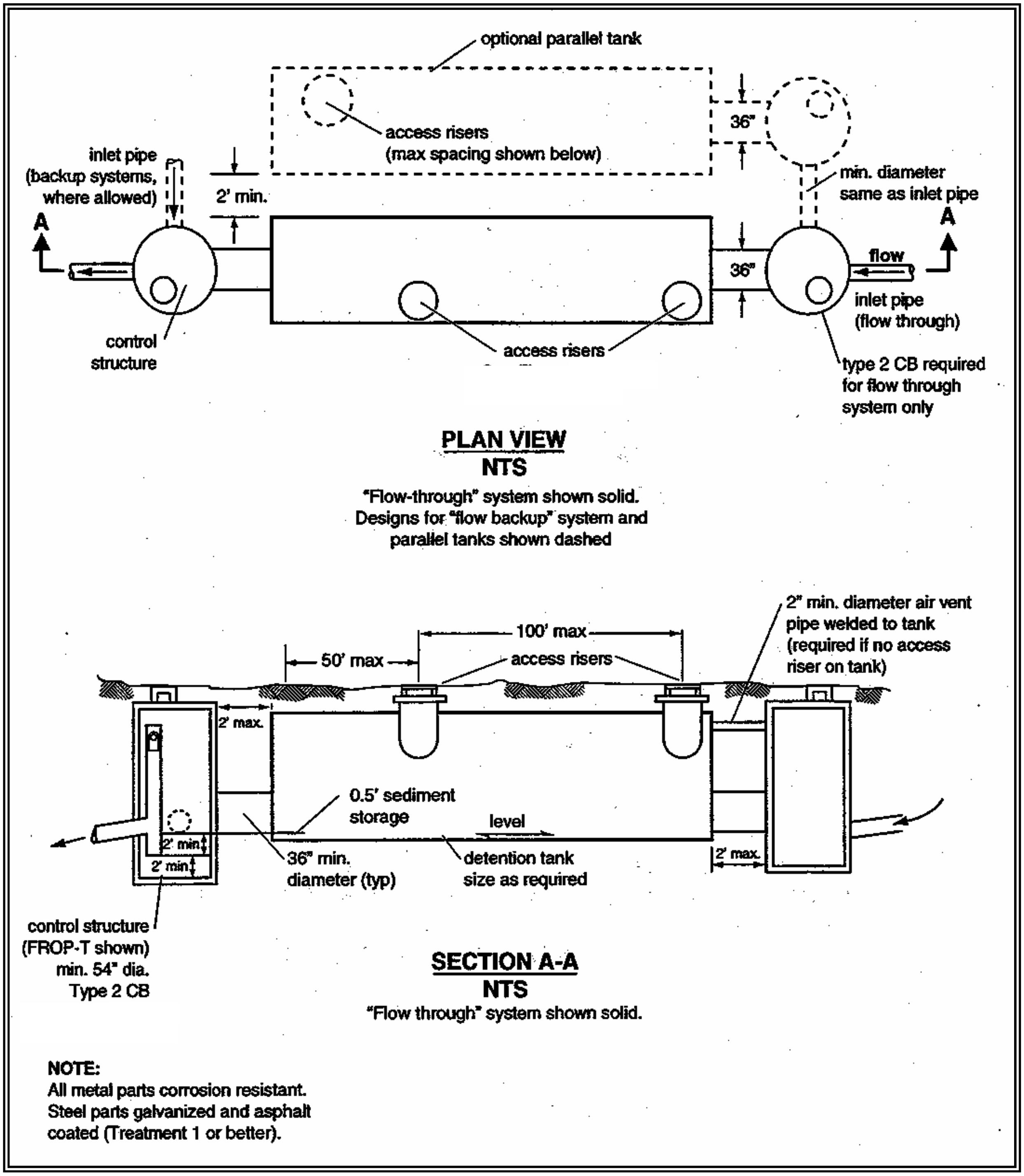


Figure 6.2.5 – Typical detention tank

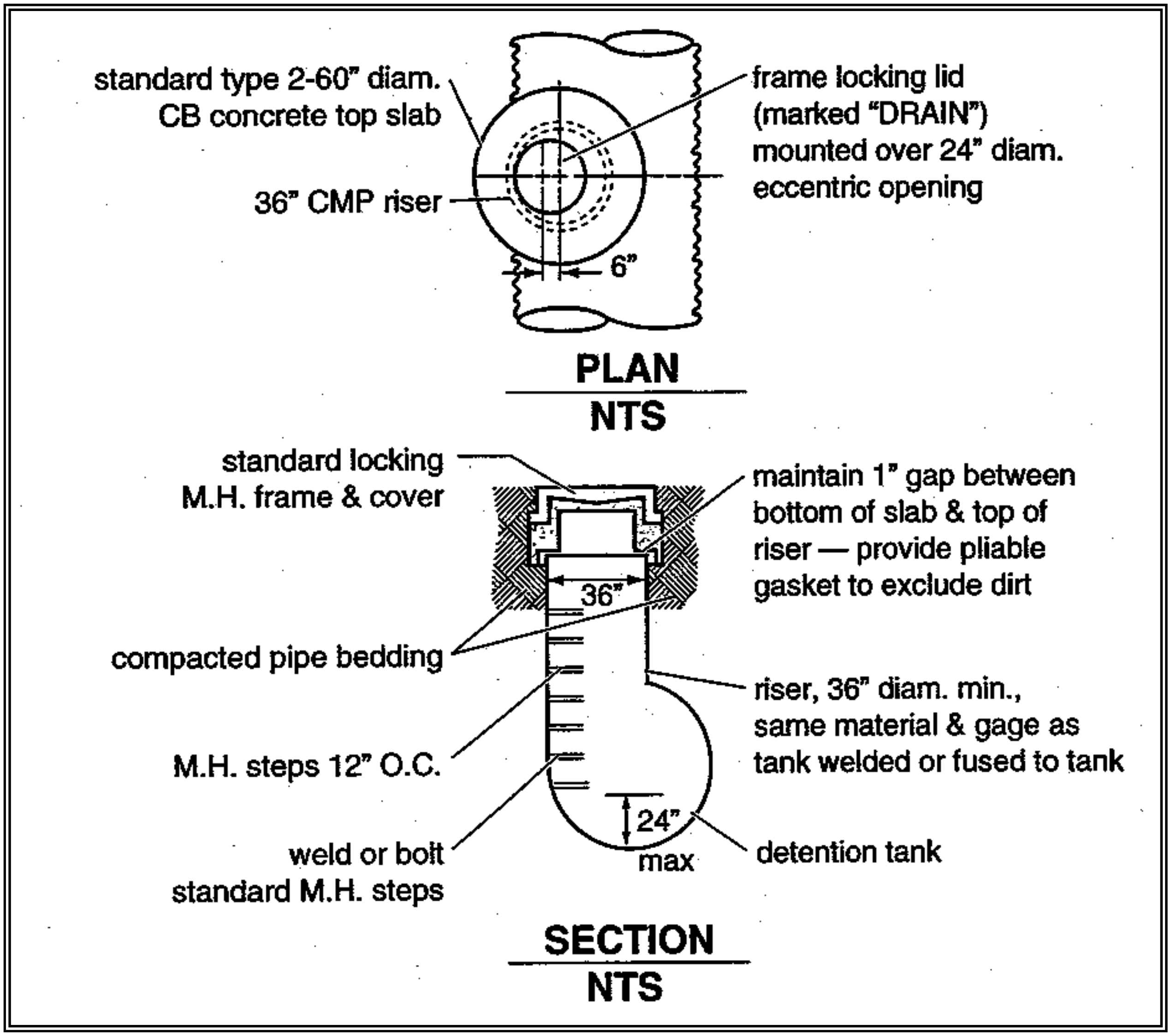


Figure 6.2.6 – Detention tank access detail

Notes for Figure 6.2.6:

Use adjusting blocks as required to bring frame to grade.
All materials to be aluminum or galvanized and asphalt coated (Treatment 1 or better).
Must be located for access by maintenance vehicles.
May substitute WSDOT special Type IV manhole (RCP only).

BMP F6.12 Detention Vaults

Detention vaults are box-shaped underground storage facilities typically constructed with reinforced concrete. A standard detention vault detail is shown in Figure 6.2.7. Control structure details are shown in Section 6.2.4. Detention vaults are not subject to UIC regulations unless the structure at the land surface is smaller than the depth of the outlet pipe *and* the pipe discharges to ground; see Chapter 5.6.

Design Criteria

General. Typical design guidelines are as follows:

1. Detention vaults may be designed as flow-through systems with bottoms level (longitudinally) or sloped toward the inlet to facilitate sediment removal. Distance between the inlet and outlet should be maximized (as feasible).

2. The detention vault bottom may slope at least 5 percent from each side towards the center, forming a broad “v” to facilitate sediment removal. More than one “v” may be used to minimize vault depth. However, the vault bottom may be flat with 0.5-1 foot of sediment storage if removable panels are provided over the entire vault. It is recommended that the removable panels be at grade, have stainless steel lifting eyes, and weigh no more than 5 tons per panel.

3. The invert elevation of the outlet should be elevated above the bottom of the vault to provide an average 6 inches of sediment storage over the entire bottom. The outlet should also be elevated a minimum of 2 feet above the orifice to retain oil within the vault.

Materials. Minimum 3,000 psi structural reinforced concrete may be used for detention vaults. All construction joints must be provided with water stops.

Structural Stability. All vaults must meet structural requirements for overburden support and H-20 traffic loading (See Standard Specifications for Highway Bridges, 1998 Interim Revisions, American Association of State Highway and Transportation Officials). Vaults located under roadways must meet any live load requirements of the local government. Cast-in-place wall sections must be designed as retaining walls. Structural designs for cast-in-place vaults must be stamped by a licensed civil engineer with structural expertise. Vaults must be placed on stable, well-consolidated native material with suitable bedding. Vaults must not be placed in fill slopes, unless analyzed in a geotechnical report for stability and constructability.

Access. Access must be provided over the inlet pipe and outlet structure. The following guidelines for access may be used.

1. Access openings should be positioned a maximum of 50 feet from any location within the tank. Additional access points may be needed on large vaults. If more than one “v” is provided in the vault floor, access to each “v” must be provided.

2. For vaults with greater than 1,250 square feet of floor area, a 5' by 10' removable panel should be provided over the inlet pipe (instead of a standard frame, grate and solid cover). Alternatively, a separate access vault may be provided.
3. For vaults under roadways, the removable panel must be located outside the travel lanes. Alternatively, multiple standard locking manhole covers may be provided. Ladders and hand-holds need only be provided at the outlet pipe and inlet pipe, and as needed to meet OSHA confined space requirements. Vaults providing manhole access at 12-foot spacing need not provide corner ventilation pipes as specified in Item 10 below.
4. All access openings, except those covered by removable panels, may have round, solid locking lids, or 3-foot square, locking diamond plate covers.
5. Vaults with widths 10 feet or less must have removable lids.
6. The maximum depth from finished grade to the vault invert should be 20 feet.
7. Internal structural walls of large vaults should be provided with openings sufficient for maintenance access between cells. The openings should be sized and situated to allow access to the maintenance "v" in the vault floor.
8. The minimum internal height should be 7 feet from the highest point of the vault floor (not sump), and the minimum width should be 4 feet. However, concrete vaults may be a minimum 3 feet in height and width if used as tanks with access manholes at each end, and if the width is no larger than the height. Also the minimum internal height requirement may not be needed for any areas covered by removable panels.
9. Vaults must comply with the OSHA confined space requirements, which includes clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser(s), just under the access lid.
10. Ventilation pipes (minimum 12-inch diameter or equivalent) should be provided in all four corners of vaults to allow for artificial ventilation prior to entry of maintenance personnel into the vault. Alternatively removable panels over the entire vault may be provided.

Access Roads. Access roads are needed to the access panel (if applicable), the control structure, and at least one access point per cell, and they may be designed and constructed as specified for detention ponds in Section 6.2.1.

Right-of-Way. Right-of-way is needed for detention vaults maintenance. It is recommended that any tract not abutting public right-of-way should have a 15 to 20-foot wide extension of the tract to accommodate an access road to the facility.

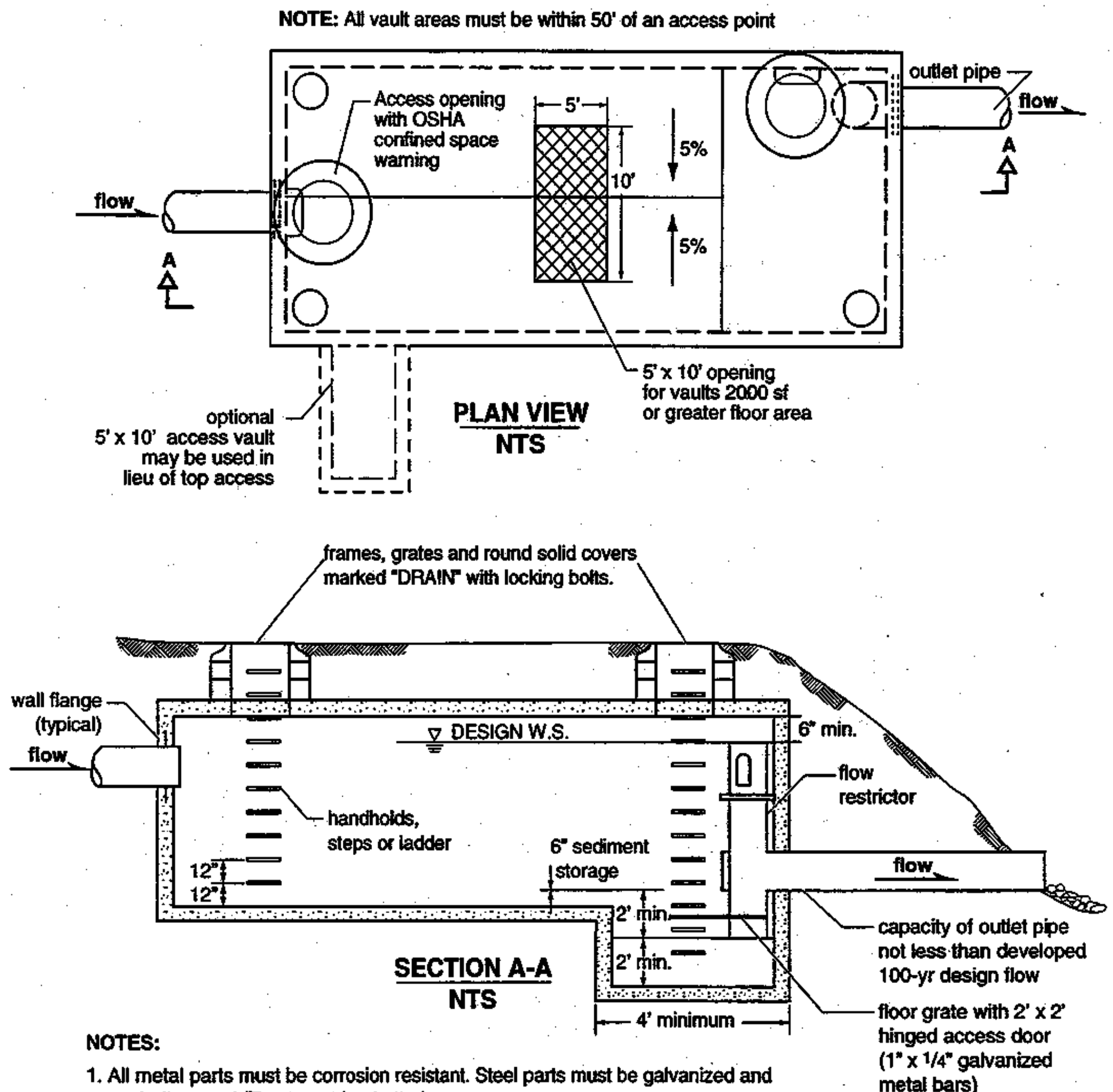
Setbacks. It is recommended that facilities be a minimum of 20 feet from any structure, property line, and any vegetative buffer required by the local government and from any septic drainfield. However, the setback requirements are generally specified by the local government, uniform building code, or other statewide regulation and may be different from those mentioned above.

The design professional should carefully consider and evaluate any situation where a pond will be situated upslope from a structure or behind the top of a slope inclined in excess of 15 percent. The minimum setback from such a slope is equal to 'h', the height of the slope, unless the design professional can justify a lesser setback based on a comprehensive site evaluation.

Maintenance. Provisions to facilitate maintenance operations must be built into the project when it is installed. Maintenance must be a basic consideration in design and in determination of first cost. See Appendix 6A for specific maintenance requirements.

Methods of Analysis

Detention Volume and Outflow. The volume and outflow design for detention vaults must be in accordance with the requirements of the regulatory agency and the hydrologic analysis and design methods in Chapter 4. Restrictor and orifice design are given in Section 6.2.4.



NOTES:

1. All metal parts must be corrosion resistant. Steel parts must be galvanized and asphalt coated (Treatment I or better).
2. Provide water stop at all cast-in-place construction joints. Precast vaults shall have approved rubber gasket system.
3. Vaults ≤ 10' wide must use removable lids.
4. Prefabricated vault sections may require structural modifications to support 5' x 10' opening over main vault. Alternatively, access can be provided via a side vestibule as shown.

Figure 6.2.7 – Typical detention vault

6.2.2 Control Structures

Control structures are catch basins or manholes with a restrictor device for controlling outflow from a facility to meet the desired performance. Riser type restrictor devices ("tees") or flow restrictor oil pollution control tees ("FROP-Ts") also provide some incidental oil/water separation to temporarily detain oil or other floatable pollutants in runoff due to accidental spill or illegal dumping.

The restrictor device usually consists of two or more orifices and/or a weir section sized to meet performance requirements.

Standard control structure details are shown in Figures 6.2.8 and 6.2.9.

Design Criteria

Multiple Orifice Restrictor. In most cases, control structures need only two orifices: one at the bottom and one near the top of the riser, although additional orifices may best utilize detention storage volume. Several orifices may be located at the same elevation if necessary to meet performance requirements.

Control Structure	Pond Head
outlet pipe	very low
v-notch weir	low
slotted weir	moderate
multi-stage orifice	high

A 1-inch diameter minimum orifice is recommended, but must be confirmed with the requirements of the local jurisdiction.

1. Minimum orifice diameter is 1.0 inches, subject to confirmation by the local jurisdiction. Note: In some instances, a 0.5-inch bottom orifice will be too large to meet target release rates, even with minimal head. In these cases, the live storage depth need not be reduced to less than 3 feet in an attempt to meet the performance standards. Also, under such circumstances, flow-throttling devices may be a feasible option. These devices will throttle flows while maintaining a plug-resistant opening.
2. Orifices may be constructed on a tee section as shown in Figure 6.2.8 or on a baffle as shown in Figure 6.2.9.
3. In some cases, performance requirements may require the top orifice/elbow to be located too high on the riser to be physically constructed (e.g., a 13-inch diameter orifice positioned 0.5 feet from the top of the riser). In these cases, a notch weir in the riser pipe may be used to meet performance requirements (see Figure 6.2.12).
4. Consideration must be given to the backwater effect of water surface elevations in the downstream conveyance system. High tailwater elevations may affect performance of the restrictor system and reduce live storage volumes.

Riser and Weir Restrictor.

1. Properly designed weirs may be used as flow restrictors (see Figures 6.2.11 and 6.2.12). However, they must be designed to provide for primary overflow of the developed 25-year peak flow discharging to the detention facility.
2. The combined orifice and riser (or weir) overflow may be used to meet performance requirements; however, the design must still provide for primary overflow of the developed 25-year peak flow assuming all orifices are plugged. Figure 6.2.13 can be used to calculate the head in feet above a riser of given diameter and flow.

Access. The following guidelines for access may be used.

1. An access road to the control structure is needed for inspection and maintenance, and must be designed and constructed as specified for detention ponds in Section 6.2.1.
2. Manhole and catch basin lids for control structures must be locking, and rim elevations must match proposed finish grade.
3. Manholes and catch-basins must meet the OSHA and WISHA confined space requirements, which include clearly marking entrances to confined space areas. This may be accomplished by hanging a removable sign in the access riser, just under the access lid.

Information Plate. It is recommended that a brass or stainless steel plate be permanently attached inside each control structure with the following information engraved on the plate:

- Name and file number of project
- Name and company of (1) developer, (2) engineer, and (3) contractor
- Date constructed
- Date of manual used for design
- Outflow performance criteria
- Release mechanism size, type, and invert elevation
- List of stage, discharge, and volume at one-foot increments
- Elevation of overflow
- Recommended frequency of maintenance.

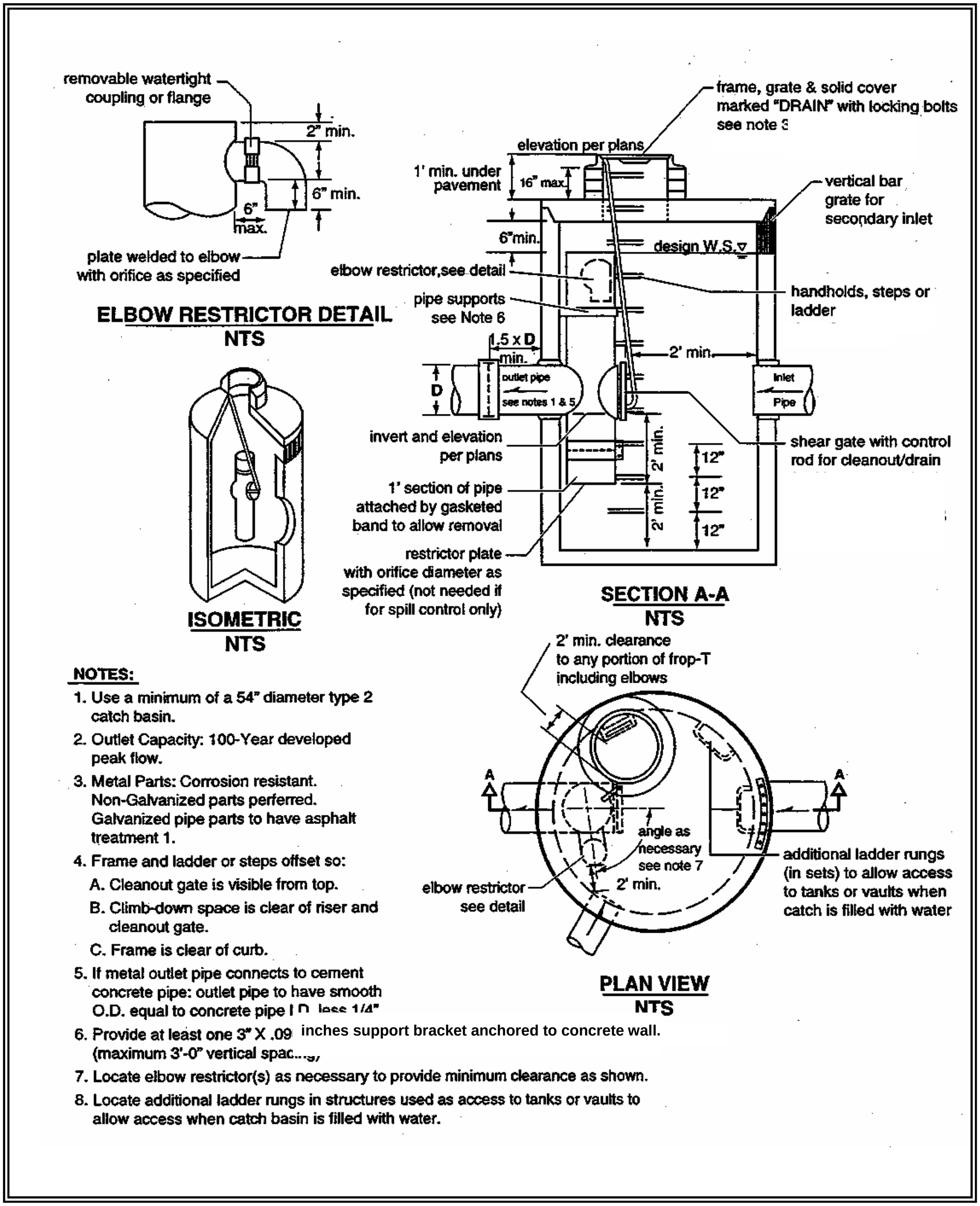
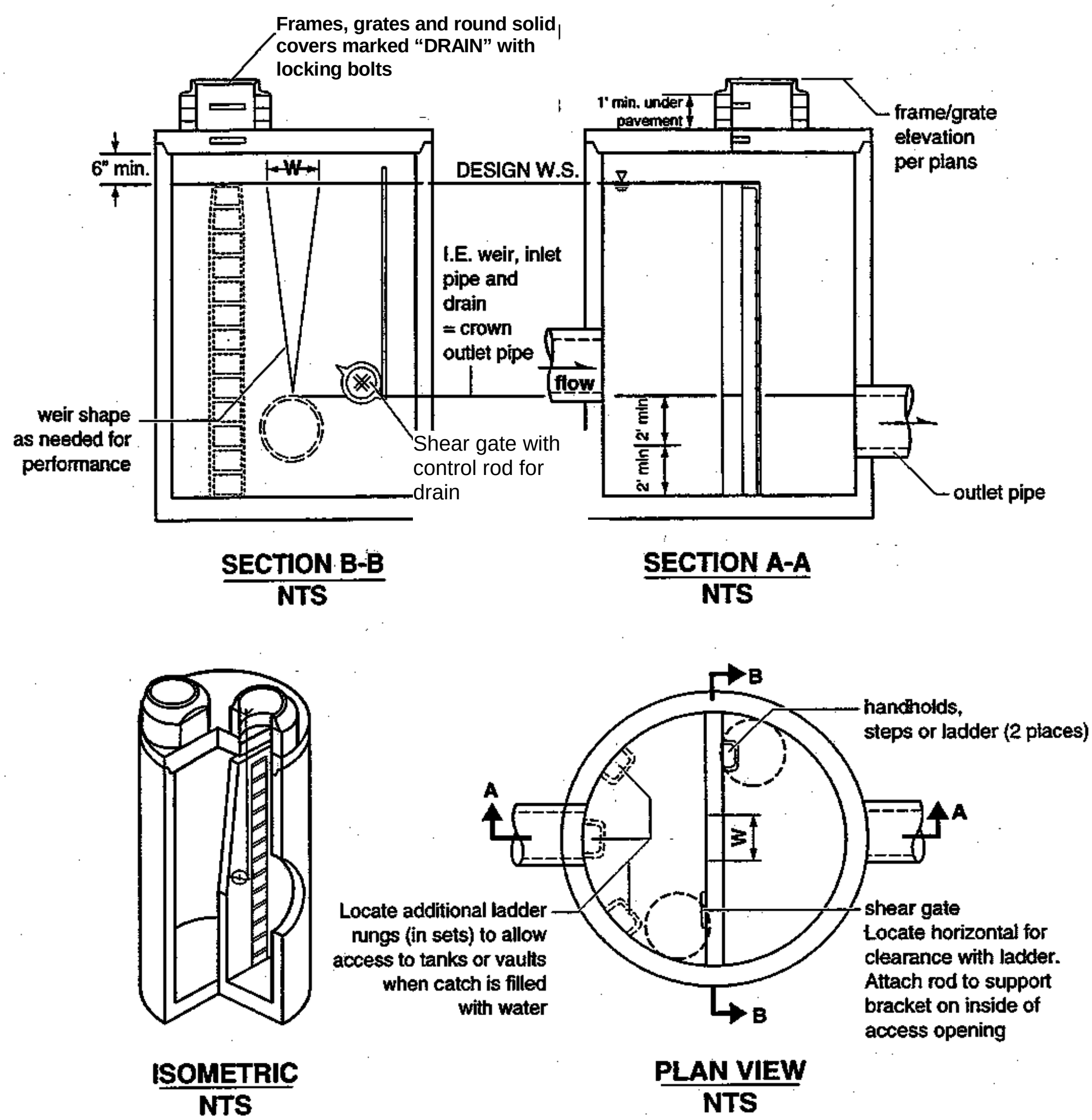


Figure 6.2.8 – Flow restrictor (Tee)



NOTES:
Outlet Capacity: 100-year developed peak flow.
Metal Parts: corrosion resistant steel parts galvanized and asphalt coated.
Catch Basin: type 2 Min. 72" diameter

Baffle Wall: to be designed with concrete reinforcing as required.
Spill containment must be provided to temporarily detain oil or floatable pollutants in runoff due to accidental spill or illegal dumping.

Figure 6.2.9 – Flow Restrictor (Weir)

Maintenance. Control structures and catch basins have a history of maintenance-related problems and it is imperative that a good maintenance program be established for their proper functioning. A typical problem is that sediment builds up inside the structure which blocks or restricts flow to the inlet. To prevent this problem these structures should be routinely cleaned out. Regular inspections of control structures should be conducted to detect the need for non-routine cleanout, especially if construction or land-disturbing activities are occurring in the contributing drainage area.

A 15-foot wide access road to the control structure should be installed for inspection and maintenance. Appendix 6A provides maintenance recommendations for control structures and catch basins.

Methods of Analysis

This section presents the methods and equations for design of control structure restrictor devices. Included are details for the design of orifices, rectangular sharp-crested weirs, v-notch weirs, sutro weirs, and overflow risers.

Orifices. Flow-through orifice plates in the standard tee section or turn-down elbow may be approximated by the general equation:

$$Q = C\,A\sqrt{2gh} \qquad \text{(Eq. 5.2.4)}$$

where Q = flow (cfs)
C = coefficient of discharge (0.62 for plate orifice)
A = area of orifice (ft^2)
h = hydraulic head (ft)
g = gravity (32.2 ft/sec^2)

Figure 6.2.10 illustrates this simplified application of the orifice equation.

The diameter of the orifice is calculated from the flow. The orifice equation is often useful when expressed as the orifice diameter in inches:

$$d = \sqrt{\frac{36.88Q}{\sqrt{h}}} \qquad \text{(Eq. 5.2.5)}$$

where *d* = orifice diameter (inches)
Q = flow (cfs)
h = hydraulic head (ft)

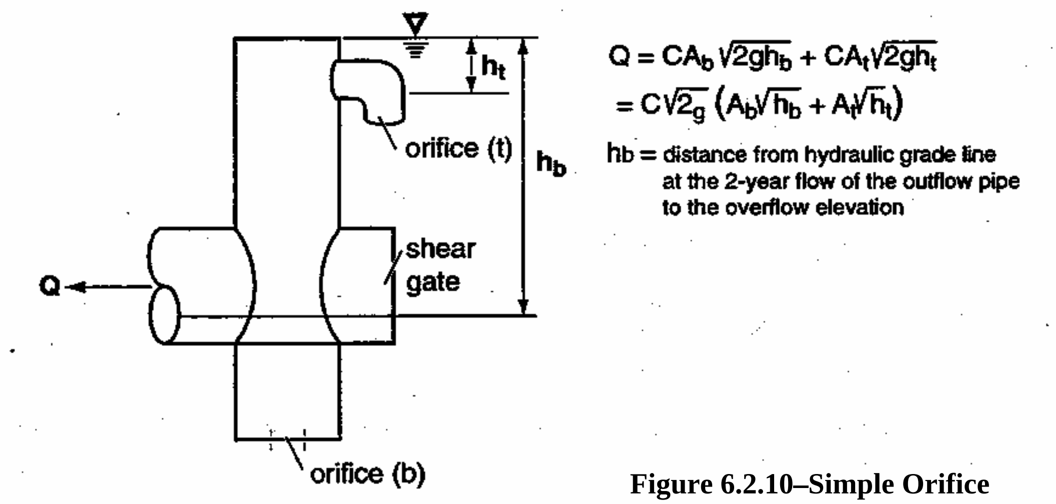


Figure 6.2.10–Simple Orifice

Rectangular Sharp-Crested Weir. The rectangular sharp-crested weir design shown in Figure 6.2.11 may be analyzed using standard weir equations for the fully contracted condition.

$$Q=C\,(L - 0.2H)H^{3/2} \qquad \text{(Eq. 5.2.6)}$$

where Q = flow (cfs)
C = 3.27 + 0.40 H/P (ft)
H, P are as shown below
L = length (ft) of the portion of the riser circumference as necessary, not to exceed 50 percent of the circumference
D = inside riser diameter (ft)

Note *that this equation accounts for side contractions by subtracting 0.1H from L for each side of the notch weir.*

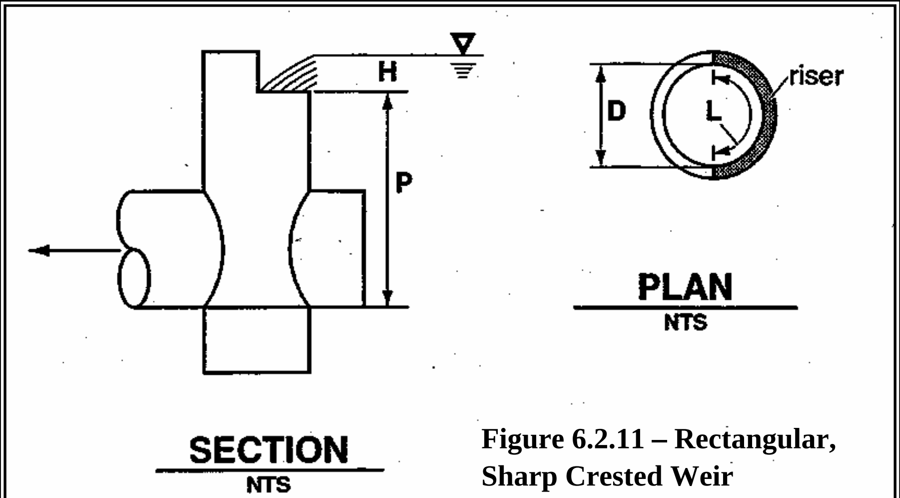
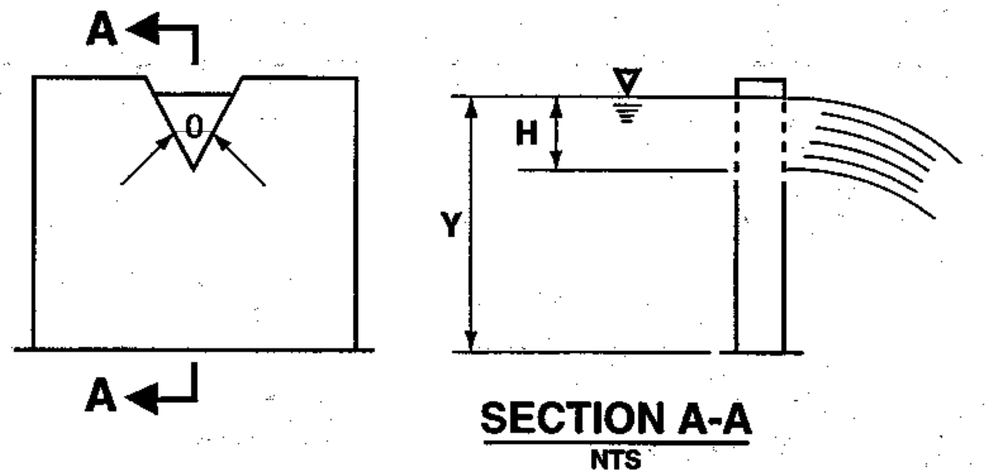


Figure 6.2.11 – Rectangular, Sharp Crested Weir

V-Notch Sharp-Crested Weir. V-notch weirs as shown in Figure 6.2.12 may be analyzed using standard equations for the fully contracted condition.



$$Q = C_d\ (\mathrm{Tan}\ \theta/2)\ H^{5/2}, \text{ in cfs}$$

Where values of C_d may be taken from the following chart:

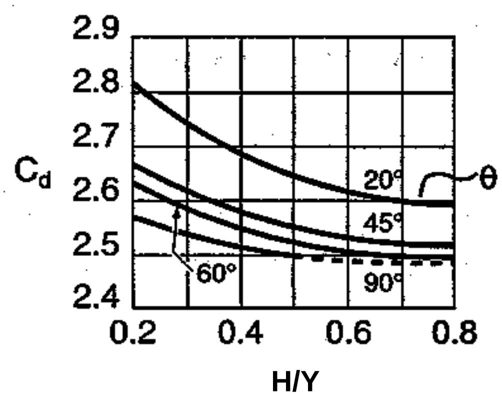


Figure 6.2.12 – V-Notch, sharp-crested weir

Riser Overflow. The nomograph in Figure 6.2.13 can be used to determine the head (in feet) above a riser of given diameter and for a given flow (usually the 25- to 100-year peak flow for developed conditions).

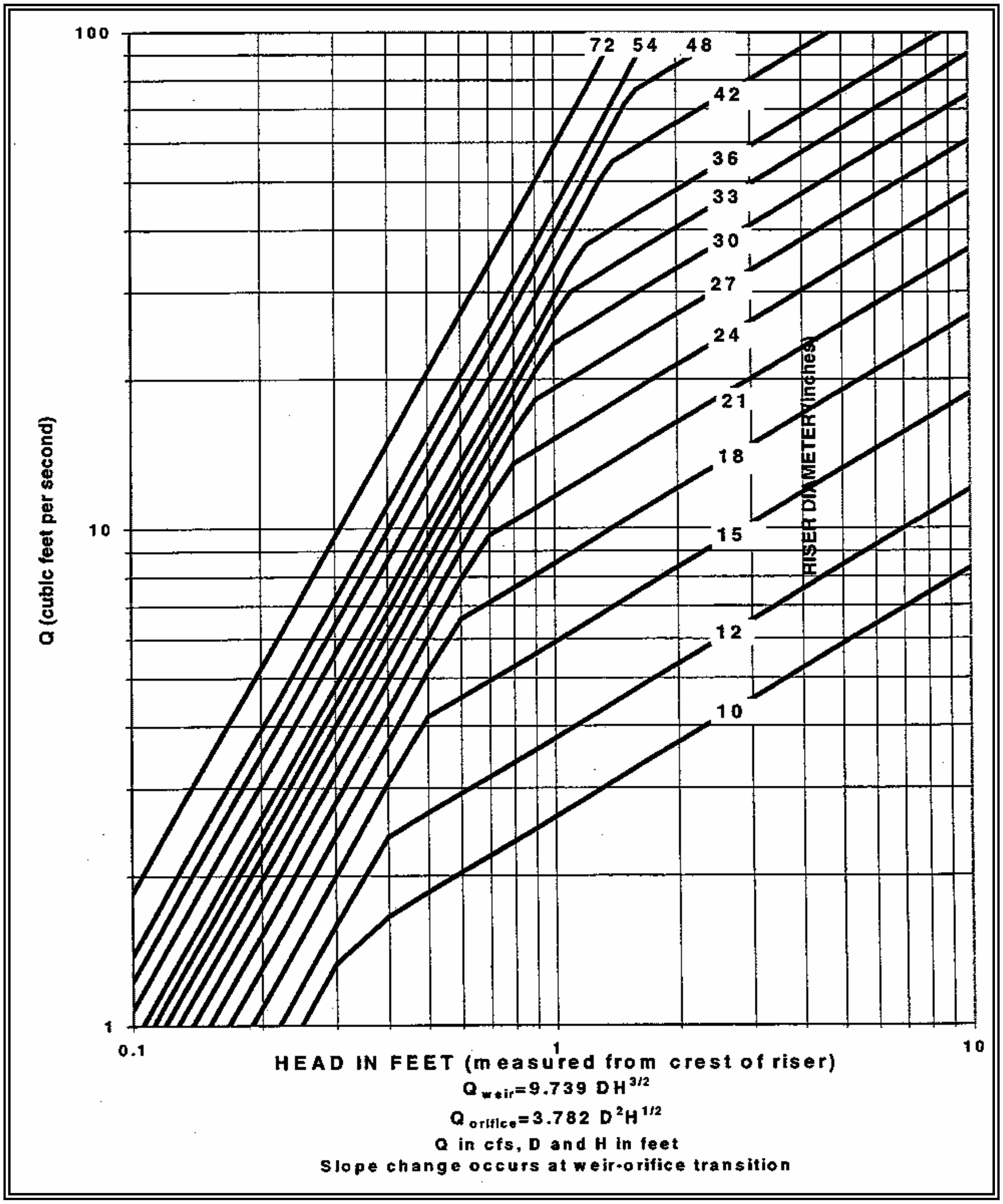


Figure 6.2.13 – Riser inflow curves

6.2.3 Supplemental Guidelines for Detention

Use of Parking Lots for Additional Detention

Parking lots may be used to provide additional detention volume for runoff events greater than the design storm, provided all of the following are met:

1. The depth of water detained does not exceed 1 foot (or other depth established by the permitting authority or local jurisdiction) at any location in the parking lot for runoff events up to and including the 100-year event.
2. The gradient of the parking lot area subject to ponding is 1 percent or greater.
3. The emergency overflow path is identified and noted on the engineering plan. The overflow must not create a significant adverse impact to downhill properties or drainage system.
4. Fire lanes used for emergency equipment are free of ponding water for all runoff events up to and including the 100-year event.
5. A downstream treatment facility with absorptive oil removal is needed prior to discharge to surface or ground water.

6.3 Infiltration of Stormwater for Quantity Control

6.3.1 Description

An infiltration BMP is typically an open basin (pond), trench, or buried perforated pipe used for distributing the stormwater runoff into the underlying soil (See Figure 6.3.2). Stormwater drywells receiving uncontaminated or properly treated stormwater can also be considered as infiltration facilities. (See Underground Injection Control Program, Chapter 173-218 WAC and Chapter 5.6 in this Manual).

Coarser more permeable soils can be used for quantity control provided that the stormwater discharge does not cause a violation of ground water quality criteria. Treatment for removal of TSS, oil, and/or soluble pollutants may be necessary prior to conveyance to an infiltration BMP. Companion practices, such as street sweeping, catch basin inserts, and similar BMPs can provide additional benefit, and reduce the cleaning and maintenance needs for the infiltration facility. The hydraulic design goal should be to mimic the natural hydrologic balance between surface and groundwater.

6.3.2 Applications

Infiltration facilities are used to convey stormwater runoff from new development or redevelopment to the ground and ground water after appropriate treatment. Runoff in excess of the infiltration capacity must be detained and released in compliance with the flow control requirements of the local jurisdiction.

Infiltration facilities may be used for quantity control where treatment is not required or for flows greater than the water quality design storm, or where runoff is treated prior to discharge. See Susceptibility Rating Tables 5.6.1 to 5.6.3 and the matrix of treatment requirements in Table 5.6.4 for determining when treatment is required prior to infiltration.

Discharge of uncontaminated or properly treated stormwater to drywells must be done in compliance with Ecology's UIC regulations (Chapter 173-218 WAC); see Chapter 5.6.

Benefits of infiltration include:

- Ground water recharge
- Retrofits in limited land areas: Infiltration trenches can be considered for residential lots, commercial areas, parking lots, and open space areas.
- Flood control
- Streambank erosion control

Site Suitability Criteria (SSC)

Not all sites are suitable for infiltration facilities. The following Site Suitability Criteria should be considered when evaluating a site for its ability to utilize infiltration.

SSC-1 Setback Criteria

Setback requirements are generally required by local regulations, uniform building code requirements, or other state regulations.

These Setback Criteria are provided as guidance.

- Stormwater infiltration facilities should be set back at least 100 feet from drinking water wells, septic tanks or drainfields, and springs used for public drinking water supplies. Infiltration facilities upgradient of drinking water supplies and within 1, 5, and 10-year time of travel zones, and special zones, must comply with Health Dept. requirements (Washington Wellhead Protection Program, DOH, 12/93).
- Additional setbacks must be considered if roadway deicers or herbicides are likely to be present in the influent to the infiltration system
- From building foundations; ≥20 feet downslope and ≥100 feet upslope
- From a Native Growth Protection Easement (NGPE); ≥20 feet
- The design professional should carefully consider and evaluate any situation where a pond will be situated upslope from a structure or behind the top of a slope inclined in excess of 15 percent. The minimum setback from such a slope is equal to 'h', the height of the slope, unless the design professional can justify a lesser setback based on a comprehensive site evaluation.

- Evaluate on-site and off-site structural stability due to extended sub-grade saturation and/or head loading of the permeable layer, including the potential impacts to down-gradient properties, especially on hills with known side-hill seeps.

SSC-2 Ground Water Protection Areas

A site is not suitable if the infiltration facility will cause a violation of Ecology's Ground Water Quality Standards. Local jurisdictions should be consulted for applicable pollutant removal requirements upstream of the infiltration facility, and to determine whether the site is located in an aquifer sensitive area, sole source aquifer, or a wellhead protection zone.

SSC-3 High Vehicle Traffic Areas

An infiltration BMP may be considered for runoff from areas of industrial activity and the high vehicle traffic areas described below. For such applications sufficient pollutant removal (including oil removal) must be provided upstream of the infiltration facility to ensure that ground water quality standards will not be violated and that the infiltration facility is not adversely affected.

High Vehicle Traffic Areas are:

- Commercial or industrial sites subject to an expected average daily traffic count (ADT) ≥100 vehicles/1,000 ft² gross building area (trip generation), and
- Road intersections with an ADT of ≥ 25,000 on the main roadway, or ≥ 15,000 on any intersecting roadway.

SSC-4 Soil Infiltration Rate/Drawdown Time

Design to completely drain ponded runoff within 72 hours after flow to it has stopped.

SSC-5 Depth to Bedrock, Water Table, or Impermeable Layer

The base of all infiltration basins or trench systems should be ≥ 5 feet above the seasonal high-water mark, bedrock (or hardpan) or other low permeability layer. A separation down to 3 feet may be considered if the ground water mounding analysis, volumetric receptor capacity, and the design of the overflow and/or bypass structures are judged by the design professional to be adequate to prevent overtopping and meet the site suitability criteria specified in this section.

SSC-6 Previously contaminated soils or unstable soils

The design professional should investigate whether the soil under the proposed infiltration facility has contaminants that could be transported by infiltrate from the facility. If so, measures should be taken for remediation of the site prior to construction of the facility, or an alternative location should be chosen. The designer should also determine if the soil beneath the proposed infiltration facility is unstable, due to improper placement of fill, subsurface geologic features, etc. If so, further investigation and planning should be undertaken prior to siting of the facility.

6.3.3 Determination of Infiltration Rates

Many qualitative and quantitative procedures have been developed to estimate the infiltration rates of soils, including those created by the American Society for Testing and Materials (ASTM), the Soil Conservation Service (SCS), American Association of State Highway and Transportation Officials (AASHTO), and the Bureau of Reclamation. Common field and laboratory test procedures include the constant-head permeability test, test pits, and the borehole percolation test.

A reliable, cost-effective approach to estimating infiltrative capacities of soils is based on standard laboratory grain size analysis (ASTM D2487-90) and/or Atterberg limits determinations (ASTM D4318-84), in conjunction with the ASTM D2488-90 visual/manual procedure. Guidance for conducting geotechnical studies that support presumptive infiltration rates are contained in Appendix 6B. Infiltration rates for surface BMPs are shown in Table 5.4.1.

6.3.4 General Design, Maintenance, and Construction Criteria for Infiltration Facilities

This section covers design, construction and maintenance criteria that apply to subsurface infiltration facilities such as drywells, infiltration basins, and trenches.

Design Criteria – Sizing Facilities

The size of the infiltration facility can be determined by routing the appropriate stormwater runoff through it. To prevent the onset of anaerobic conditions, the infiltration facility must be designed to drain completely 72 hours after the flow to it has stopped.

Inflow to infiltration facilities is calculated according to the methods described in Chapter 4. The storage volume in the pond, drywell, perforated pipe, or voids in the gravel, is used to detain runoff prior to infiltration. The infiltration rate and size of the infiltration area are used in conjunction with the size of the storage area to design the facility.

In general, an infiltration facility should have two discharge modes. The primary mode of discharge from an infiltration facility is infiltration into the ground. However, when the infiltration capacity of the facility is reached, additional runoff to the facility will cause the facility to overflow. Overflows from an infiltration facility must comply with the requirements of the local jurisdiction.

Additional Design Criteria

Slope of the base of the infiltration facility should be less than 3 percent.

Spillways/Overflow structures- A nonerodible outlet or spillway with a firmly established elevation must be constructed to discharge overflow. Ponding depth, drawdown time, and storage volume are calculated from that reference point.

Construction Criteria

Excavate infiltration trenches and basins to final grade only after construction has been completed and all upgradient soil has been stabilized. Initial basin excavation should be conducted to within 1-foot of the final elevation of the basin floor. Any accumulation of silt in the infiltration facility must be removed before putting it in service. After construction is completed, prevent sediment from entering the infiltration facility by first conveying the runoff water through an appropriate pretreatment system such as a pre-settling basin, wet pond, or sand filter.

Infiltration facilities should generally not be used as temporary sediment traps during construction. If an infiltration facility is to be used as a sediment trap, it must not be excavated to final grade until after the upgradient drainage area has been stabilized.

Traffic Control - Relatively light-tracked equipment is recommended for this operation to avoid compaction of the basin floor. The use of draglines and trackhoes should be considered for constructing infiltration basins. The infiltration area should be flagged or marked to keep heavy equipment away.

Maintenance Criteria

Provision should be made for regular and perpetual maintenance of the infiltration basin/trench, with adequate access. Maintenance should be conducted when water remains in the basin or trench for more than 72 hours. An Operation and Maintenance Plan, approved by the local jurisdiction, should ensure maintaining the desired infiltration rate.

Debris/sediment accumulation- Removal of accumulated debris/sediment in the basin/trench should be conducted every 6 months or as needed to prevent clogging, or when water remains in the pond for greater than 72 hours.

Seepage Analysis and Control – Determine whether there would be any adverse effects caused by seepage zones on nearby building foundations, basements, roads, parking lots or sloping sites.

Verification of Performance

During the initial operation, verification of facility performance is recommended, along with a maintenance program that results in achieving expected performance levels. Operating and maintaining ground water monitoring wells is also encouraged.

6.3.5 Infiltration Facilities

BMP F6.20 Drywells

This section covers design and maintenance criteria specific for drywells. Drywells are subject to UIC regulations; see Chapter 5.6.

Description

Drywells are subsurface concrete structures, typically precast, that convey stormwater runoff into the soil matrix. They can be used as standalone structures, or as part of a larger drainage system (i.e., the overflow for a bio-infiltration swale).

Design Criteria for Infiltration Drywells

Figures 6.3.1 through 6.3.3 show infiltration drywell systems typical at the time of publication of this document. These systems are designed as specified below. Check with the local jurisdiction for outflow capacity requirements.

Drywell bottoms should be a minimum of 5 feet above seasonal high groundwater level or impermeable soil layers. Refer to the Site Suitability Criteria in this chapter.

Drywells are typically a minimum of 48 inches in diameter and approximately 5 to 10 feet deep, or more.

Filter fabric (geotextile) may need to be placed on top of the drain rock and on trench or drywell sides prior to backfilling to prevent migration of fines into the drain rock, depending on local soil conditions and local jurisdiction requirements.

Drywells should be no closer than 30 feet center to center or twice the depth, whichever is greater.

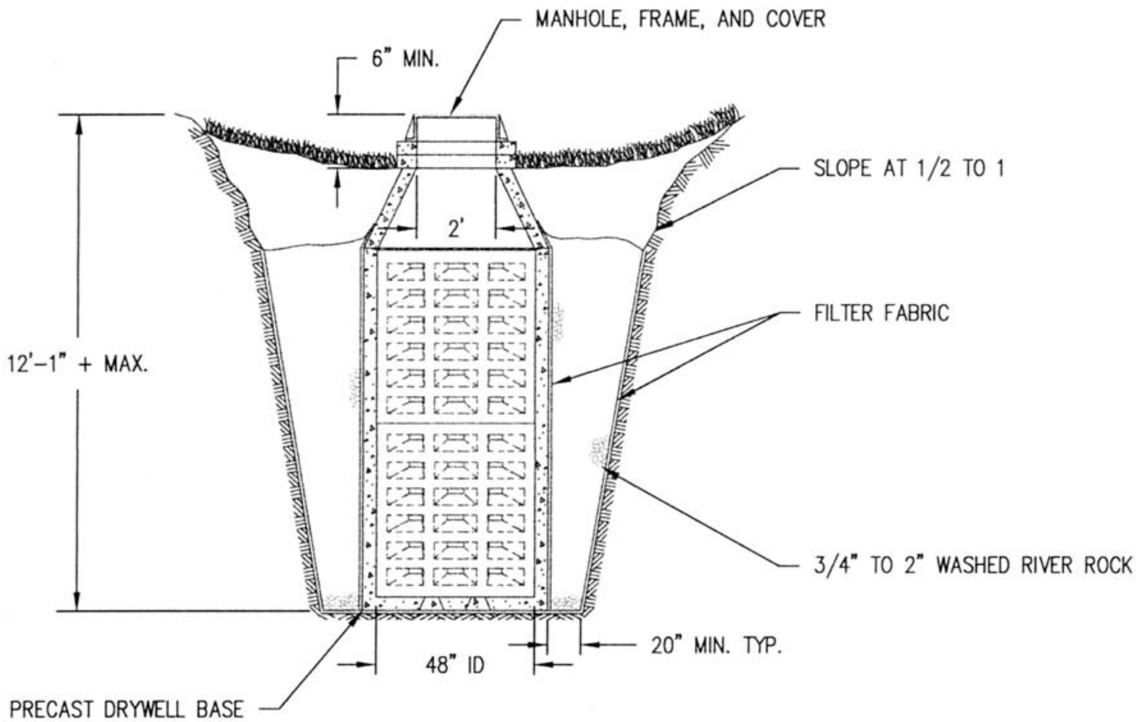
Drywells should not be built on slopes greater than 25% (4:1).

Drywells may not be placed on or above a landslide hazard area or slopes greater than 15% without evaluation by a professional engineer with geotechnical expertise or qualified geologist and jurisdiction approval.

Maintenance Criteria for Drywells

Remove debris and sediment from the drywell grate on a semi-annual basis, or as required to prevent the buildup of materials that could inhibit infiltration.

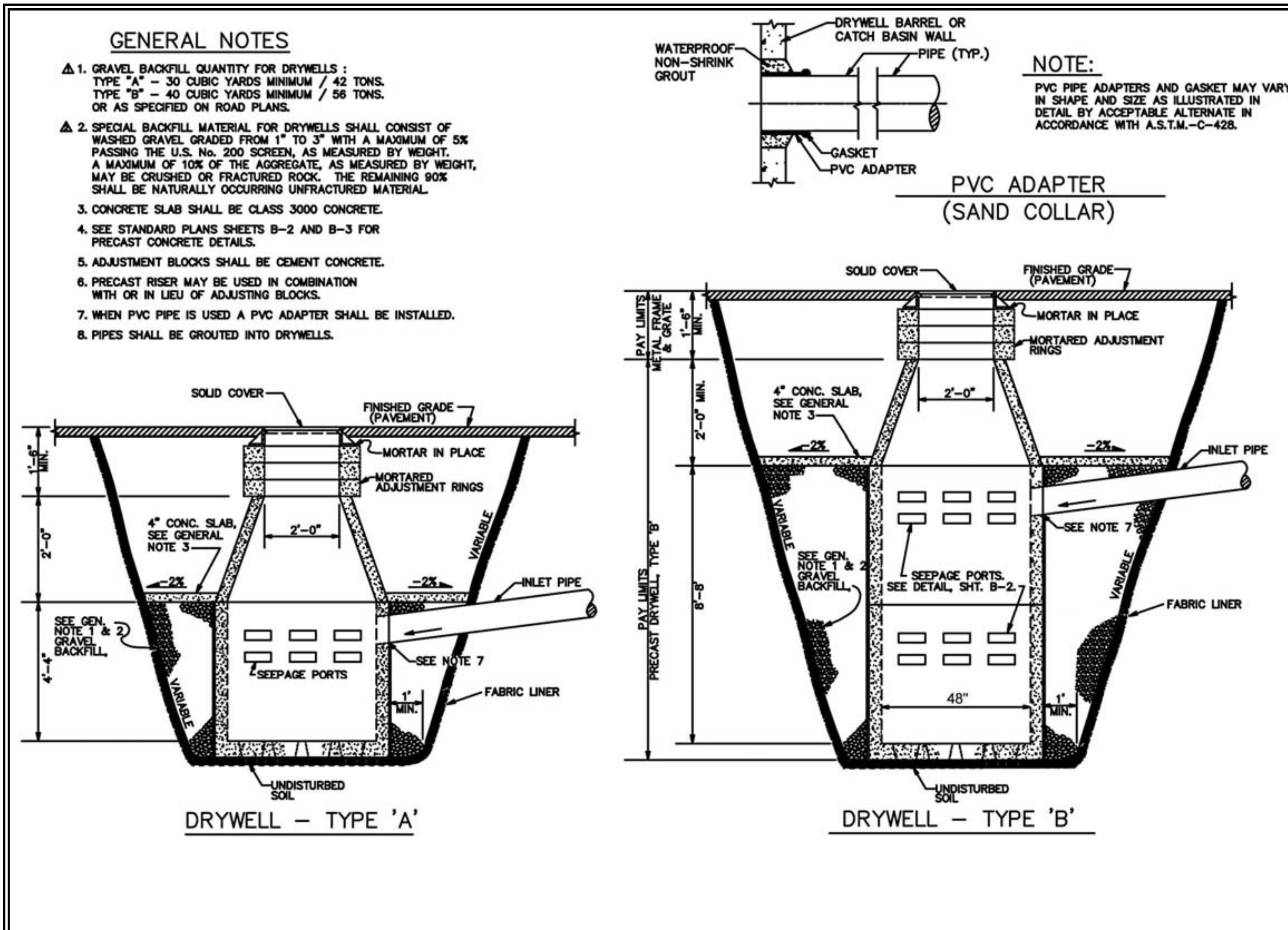
City of East Wenatchee Standard Detail



Source: RH2 Engineering, Inc., Wenatchee

Figure 6.3.1 – Sample infiltration drywell (not to scale)

Spokane County Standard Detail



Source: Spokane County Public Works

Figure 6.3.2 – Sample infiltration drywell

City of Kennewick Standard Detail

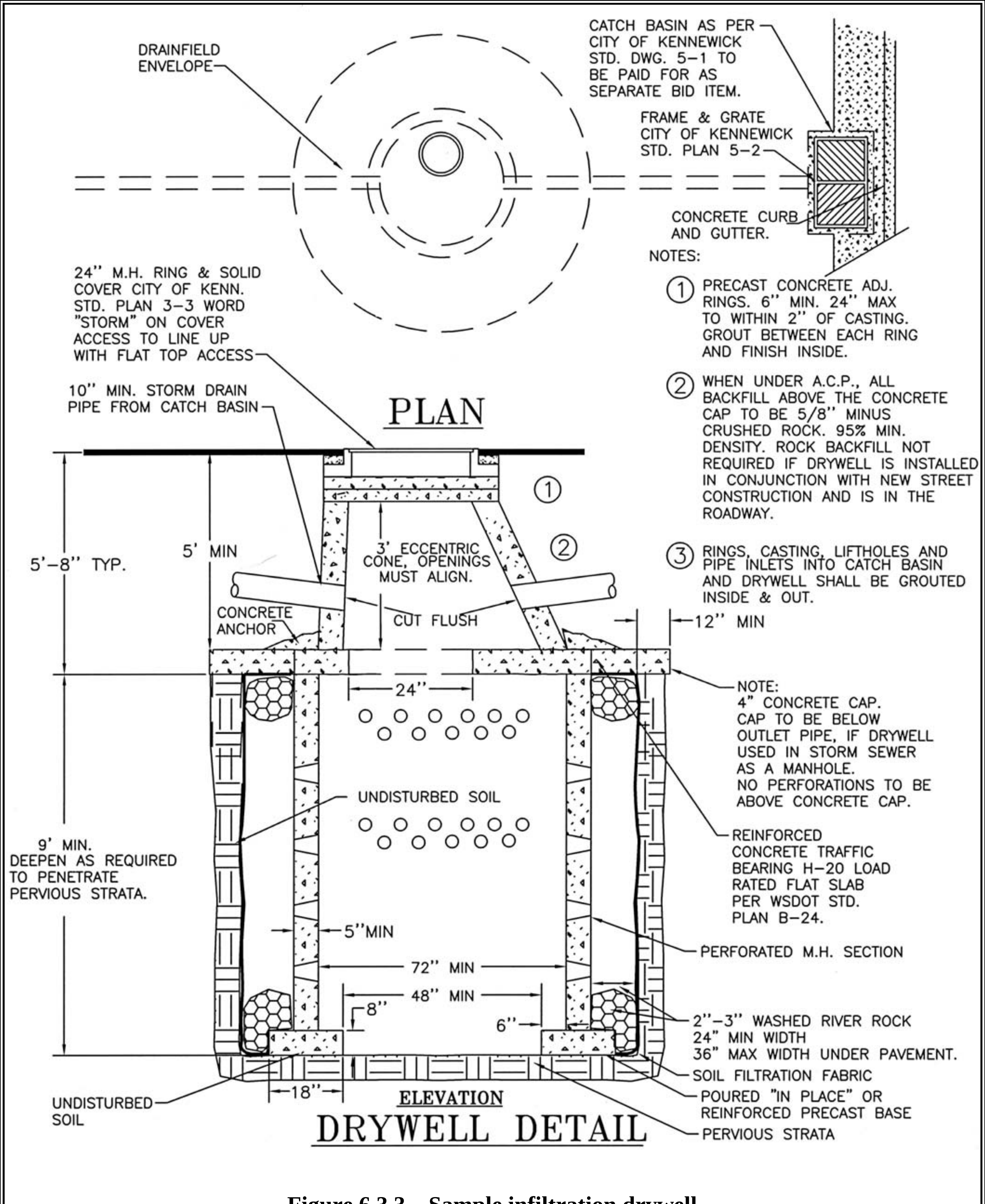


Figure 6.3.3 – Sample infiltration drywell

BMP F6.21 Infiltration Ponds

Description

Infiltration ponds are earthen impoundments used for the collection, temporary storage and infiltration of incoming stormwater runoff. This section covers design and maintenance criteria specific for infiltration ponds (see schematic in Figure 6.3.4). Infiltration ponds are not subject to UIC regulations (see Chapter 5.6).

Design Criteria

See Appendix 6B or Table 5.4.1 for design infiltration rates. Check with the local jurisdiction for outflow capacity requirements.

Access should be provided for vehicles to easily maintain the forebay (pre-settling pond) area and not disturb vegetation, or re-suspend sediment any more than is necessary. See Section 6.2.1 for design criteria regarding access roads.

A minimum of one foot of freeboard is recommended when establishing the design ponded water depth. Freeboard is measured from the rim of the infiltration facility to the maximum ponding level or from the rim down to the overflow point if overflow or a spillway is included.

Lining Material - Ponds can be open or covered with a 6 to 12-inch layer of filter material such as coarse sand, or a suitable filter fabric to help prevent the buildup of impervious deposits on the soil surface. A non-woven geotextile should be selected that will function sufficiently without plugging. The filter layer can be replaced or cleaned when/if it becomes clogged.

Vegetation – The embankment, emergency spillways, spoil and borrow areas, and other disturbed areas should be stabilized and planted, preferably with grass, in accordance with the Stormwater Site Plan (See Chapter 3). Without healthy vegetation the surface soil pores would quickly plug.

Maintenance Criteria

Maintain pond floor and side slopes to minimize erosion. This enhances infiltration, prevents erosion and consequent sedimentation of the pond floor, and prevents invasive weed growth. Where appropriate, bare spots are to be immediately stabilized and re-vegetated.

Vegetation growth should not be allowed to exceed 18 inches in height. Mow the slopes periodically and check for clogging, and erosion.

Seed mixtures should be appropriate for the climate. The use of slow-growing, stoloniferous grasses will permit long intervals between mowing. Mowing twice a year is generally satisfactory for cool season grasses; native warm season grasses should be mowed once every three years to stimulate growth. Fertilizers should be applied only as necessary and in limited amounts to avoid contributing to ground water pollution. Consult the local extension agency for appropriate fertilizer types, including slow release fertilizers, and application rates.

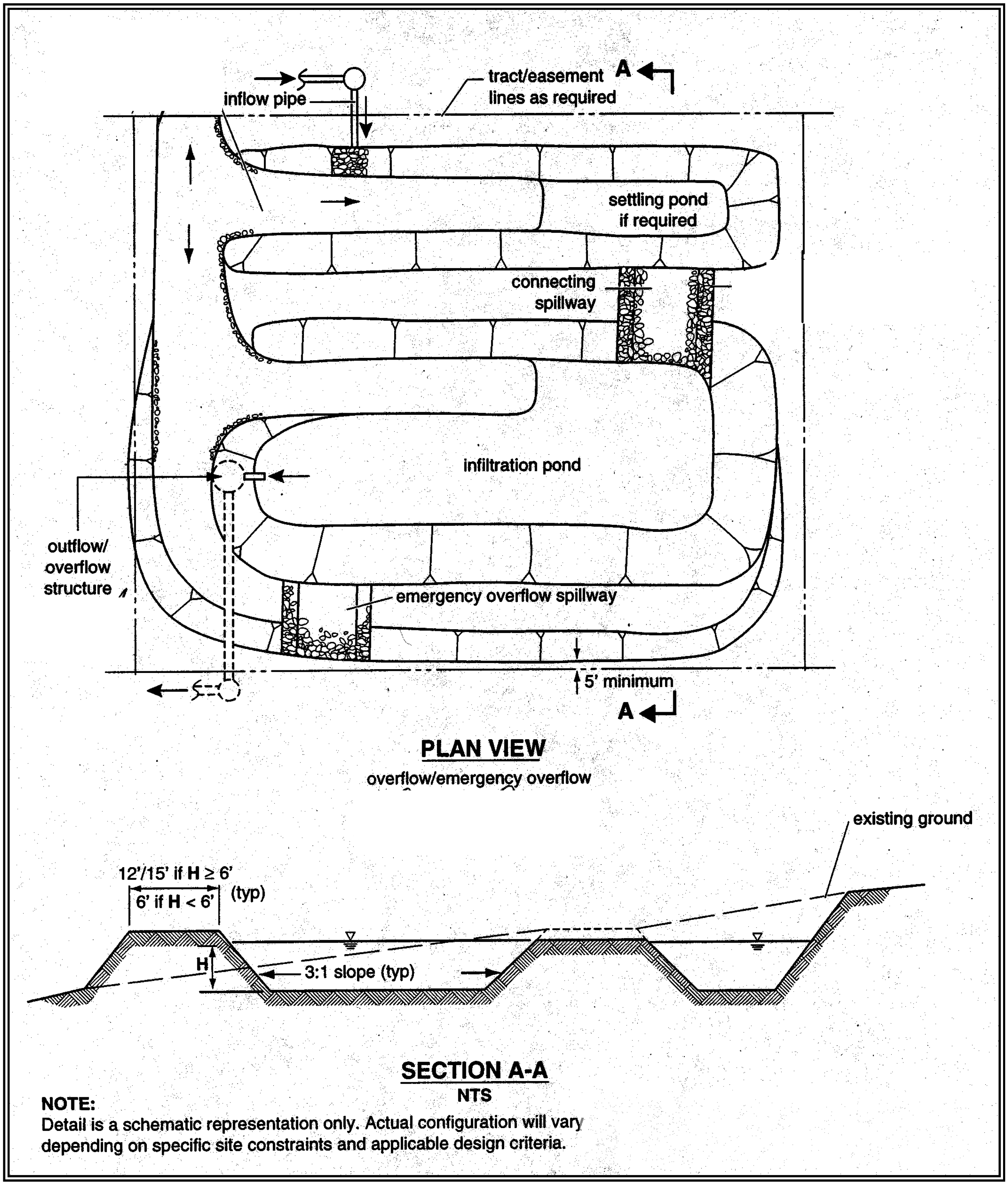


Figure 6.3.4– Typical infiltration pond

BMP F6.22 Infiltration Trenches

This section covers design, construction, and maintenance criteria specific for infiltration trenches. UIC regulations apply only when perforated pipe is installed in the trench; see Chapter 5.6.

Description

Infiltration trenches are generally at least 24 inches wide, and are backfilled with a coarse stone aggregate, allowing for temporary storage of stormwater runoff in the voids of the aggregate material. Stored runoff then gradually infiltrates into the surrounding soil. The surface of the trench can be covered with grating and/or consist of stone, gabion, sand, or a grassed covered area with a surface inlet. Perforated rigid pipe of at least 8-inch diameter can also be used to distribute the stormwater in a stone trench.

Design Criteria

See Figures 6.3.5 - 6.3.8 for examples of trench designs.

See Appendix 6B or Table 5.4.1 for design infiltration rates. Check with the local jurisdiction for outflow capacity requirements.

Due to accessibility and maintenance limitations infiltration trenches must be carefully designed and constructed. The local jurisdiction should be contacted for additional specifications.

Consider including an access port or open or grated top for accessibility to conduct inspections and maintenance.

Backfill Material - The aggregate material for the infiltration trench should consist of a clean aggregate with a maximum diameter of 3 inches and a minimum diameter of 1.5 inches. Void space for these aggregates should be in the range of 30 to 40 percent. For calculations assume a void space of 30 percent maximum.

Perforated Pipe - a minimum of 8-inch perforated pipe should be provided to increase the storage capacity of the infiltration trench and to enhance conveyance of flows throughout the trench area.

Geotextile fabric liner - The aggregate fill material shall be completely encased in an engineering geotextile material. In the case of an aggregate surface, geotextile should surround all of the aggregate fill material except for the top one-foot, which is placed over the geotextile. Geotextile fabric with acceptable properties must be carefully selected to avoid plugging.

The bottom sand or geotextile fabric as shown in the attached figures is optional.

Refer to the WSDOT Design Manual, Section 530, pages 1 through 24, where geosynthetics are discussed. This section contains information on functions and applications, types and characteristics, and design approaches. The WSDOT 2002 Standard Specifications, English units version, section 9-33, includes specifications for geotextiles, classed pursuant to the design manual discussions and definitions.

Refer to the Federal Highway Administration Manual “Geosynthetic

Design and Construction Guidelines," Publication No. FHWA HI-95-038, May 1995 for design guidance on geotextiles in drainage applications. Refer to the NCHRP Report 367, "Long-Term Performance of Geosynthetics in Drainage Applications," 1994, for long-term performance data and background on the potential for geotextiles to clog, blind, or to allow piping to occur and how to design for these issues.

Surface Cover - A stone filled trench can be placed under a porous or impervious surface cover to conserve space.

Observation Well - An observation well should be installed at the lower end of the infiltration trench to check water levels, drawdown time, sediment accumulation, and conduct water quality monitoring. Figure 6.3.9 illustrates observation well details. It should consist of a perforated PVC pipe which is 4 to 6 inches in diameter and it should be constructed flush with the ground elevation. For larger trenches a 12-36 inch diameter well can be installed to facilitate maintenance operations such as pumping out the sediment. The top of the well should be capped to discourage vandalism and tampering.

Catch Basin and Tee - A tee section should be provided in the nearest catch basin upstream of the infiltration trench if a catch basin is used. The tee will trap floatable debris and oils.

Construction Criteria

Trench Preparation - Excavated materials must be placed away from the trench sides to enhance trench wall stability. Care should also be taken to keep this material away from slopes, neighboring property, sidewalks and streets. It is recommended that this material be covered with plastic.

Stone Aggregate Placement and Compaction - The stone aggregate should be placed in lifts and compacted using plate compactors. As a rule of thumb, a maximum loose lift thickness of 12 inches is recommended. The compaction process ensures geotextile conformity to the excavation sides, thereby reducing potential piping and geotextile clogging, and settlement problems.

Potential Contamination - Prevent natural or fill soils from intermixing with the stone aggregate. All contaminated stone aggregate must be removed and replaced with uncontaminated stone aggregate.

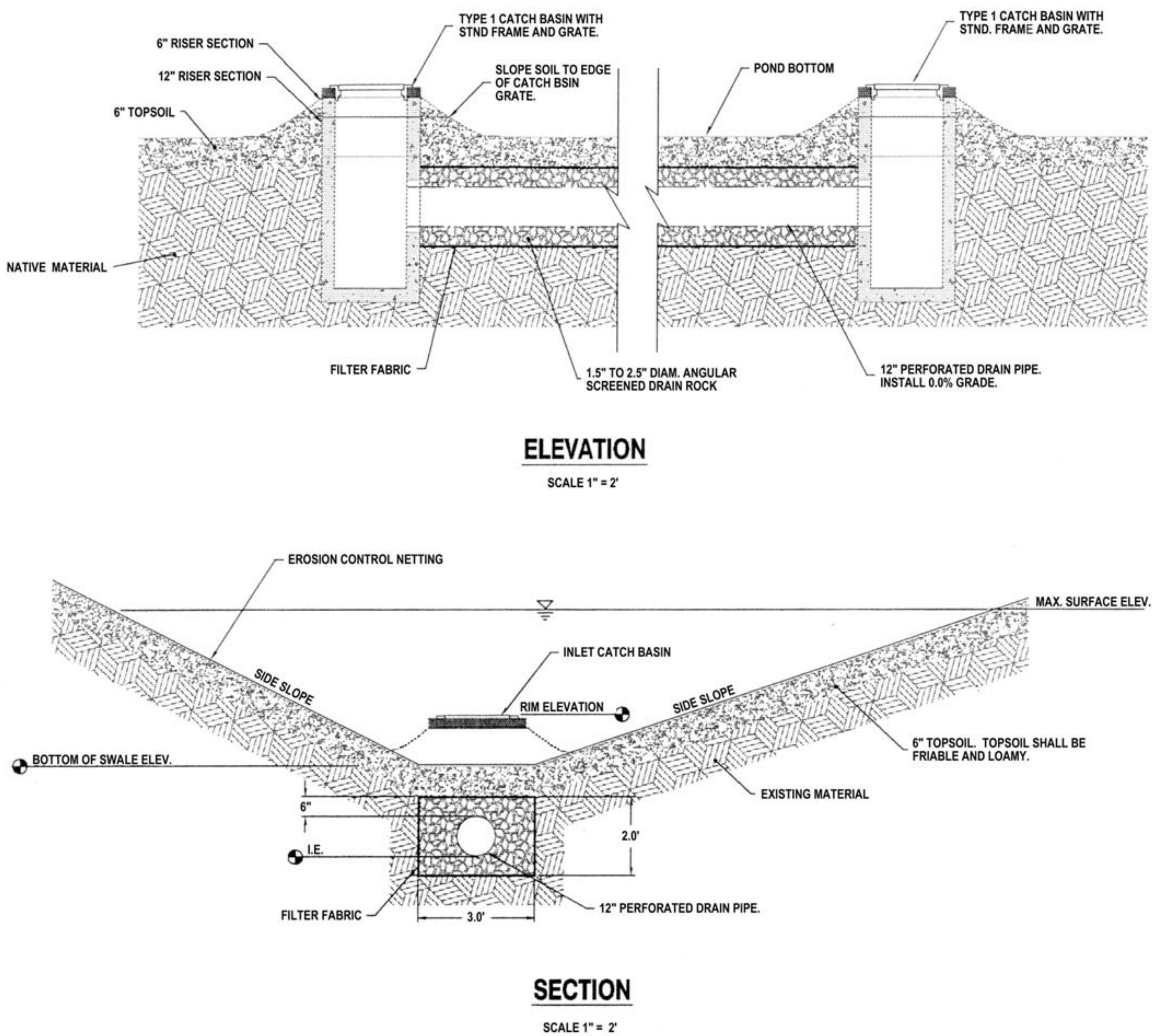
Overlapping and Covering - Following the stone aggregate placement, the geotextile must be folded over the stone aggregate to form a 12 inch minimum longitudinal overlap. When overlaps are required between rolls, the upstream roll should overlap a minimum of 2 feet over the downstream roll in order to provide a shingled effect.

Voids behind Geotextile - Voids between the geotextile and excavation sides must be avoided. Removing boulders or other obstacles from the trench walls is one source of such voids. Natural soils should be placed in these voids at the most convenient time during construction to ensure geotextile conformity to the excavation sides. Soil piping, geotextile clogging, and possible surface subsidence should be avoided by this remedial process.

Unstable Excavation Sites - Vertically excavated walls may be difficult to maintain in areas where the soil moisture is high or where soft or cohesionless soils predominate. Trapezoidal, rather than rectangular, cross-sections may be needed.

Maintenance Criteria

Sediment buildup in the top foot of stone aggregate or the surface inlet should be monitored on the same schedule as the observation well.



Source: RH2 Engineering, Inc., Wenatchee

Figure 6.3.5 – Sample infiltration trench/pond with catch basin inlet

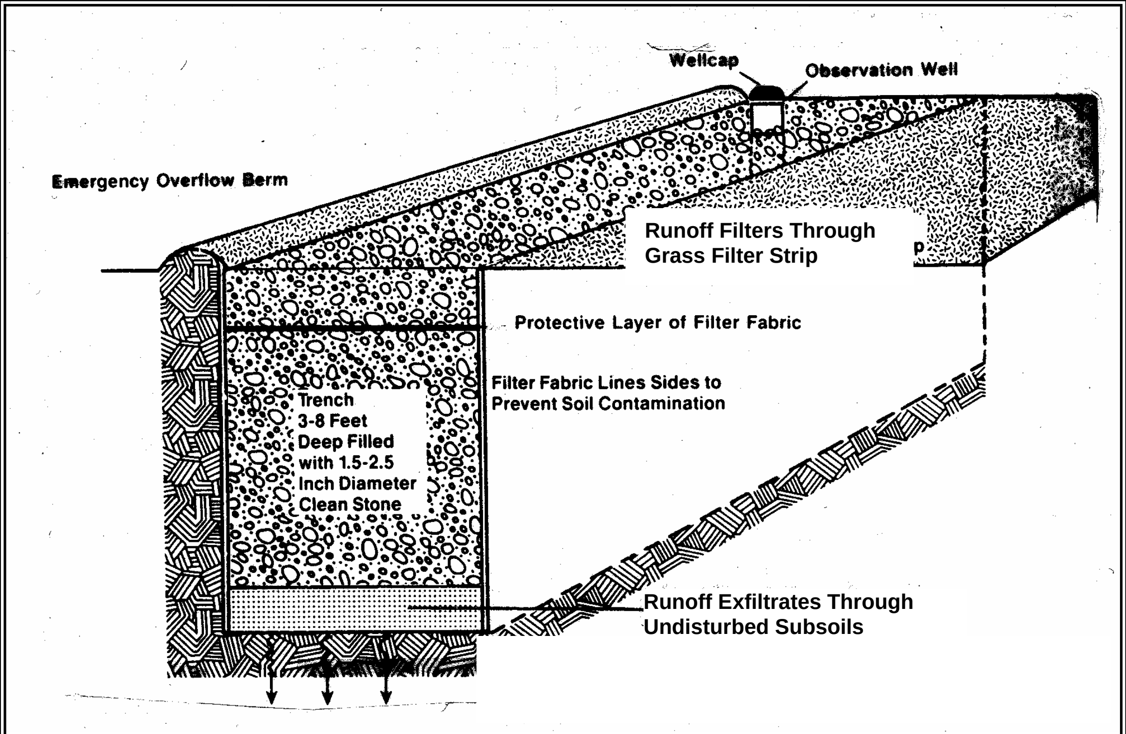
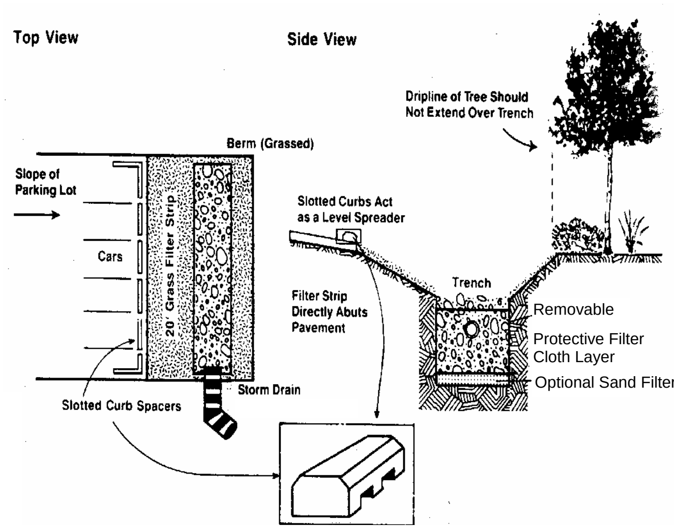
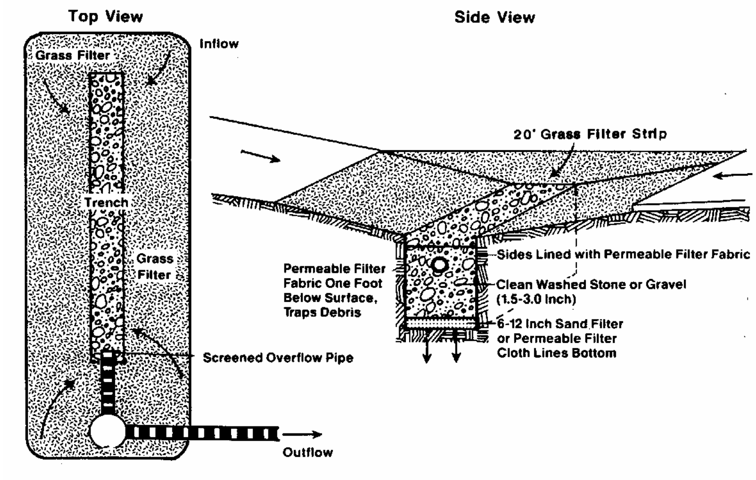


Figure 6.3.6 Schematic of infiltration trench



Source: Schueler (reproduced with permission)

Figure 6.3.7 – Parking lot perimeter trench design



Source: Schueler (reproduced with permission)

Figure 6.3.8 – Median strip trench design

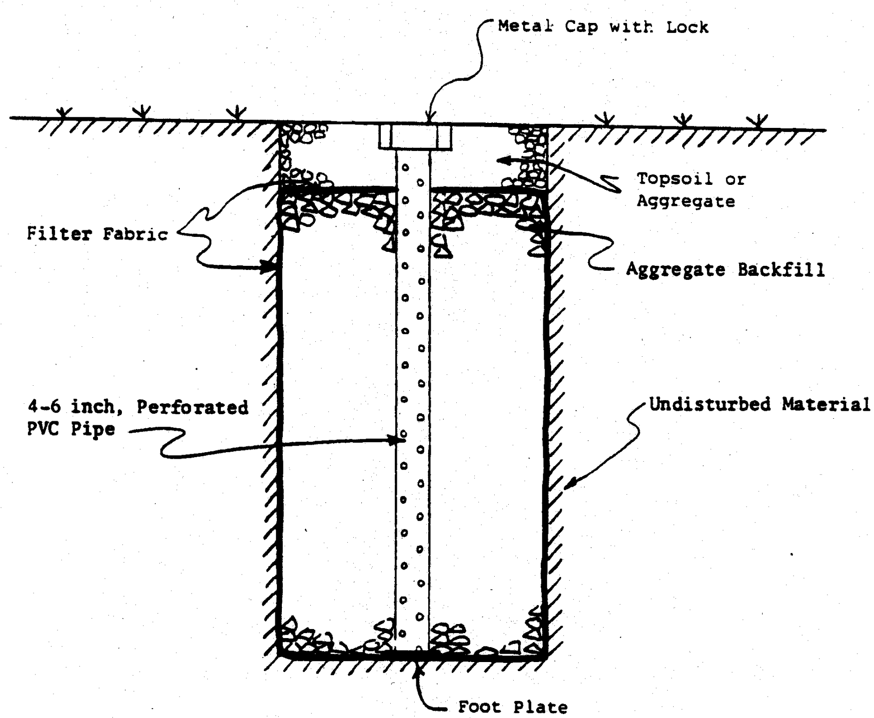


Figure 6.3.9 – Observation well details

6.4 Evaporation Ponds

This section provides the methods for the design of evaporation ponds, which can be used to collect and dispose of stormwater when surface discharge is not available or the soils are not conducive to infiltration facilities.

For the design of evaporative facilities, a water budget is required. A cumulative, month-by-month water budget is performed as follows:

$$V_{in} - V_{out} = \Delta V_{month}$$

$$\Sigma V_{month} = \Delta V_{year}$$

Where:

V_{in} Volume of water into evaporative facility, (usually cubic ft./month). V_{in} is a combination of stormwater runoff, direct rainfall onto the pond surface, groundwater seepage into evaporative facility, and any other source of water into the facility.

V_{out} Volume of water out of the evaporative facility (usually a cubic ft/month). V_{out} is all outflows, it can be a combination surface evaporation, plant evapotranspiration, ground infiltration, or any other qualified outflow.

ΔV_{month} Net volume of storage increase (or decrease) into the evaporative facility (usually cubic ft./month).

ΔV_{year} Cumulative net volume of storage in evaporative facility until storage equilibrium is obtained. Equilibrium is obtained when the volume of water in the cycle is less than the volume stored at the beginning of the cycle, evaluated over at least two calendar years.

It is recommended that a freeboard of at least 1 foot be maintained in the pond at all times. The use of a spreadsheet to perform the calculations can be helpful.

The water budget cycle should be performed on a month-by-month basis, until a steady-state condition occurs (i.e., the volume at the end of the cycle is less than or equal to the volume at the start of the cycle). The minimum duration of the water budget cycle is to be two years. The cycle is to start in the month which yields the greatest net storage volume for the year. Normally, beginning the water budget in September, October, or November produces the largest required storage volume. Contributing off-site areas are to be included in the analysis, considering existing locations.

The climatological data source for evaporation and mean annual precipitation rates used in the water budget are available from the National Oceanic and Atmospheric Administration (NOAA), or other reliable sources. The Western Region Climate Center maintains data for several western states (http://www.wrcc.dri.edu/summary/climsmwa.html). Average monthly precipitation rates and average monthly evaporation rates should be used in the water budget analysis, as a minimum.

UIC regulations do not apply to evaporation ponds (see Chapter 5.6).

6.4.1 Runoff Volume Determinations

Runoff volume from the basin directing stormwater into the evaporative systems shall be included in the water budget analysis. Runoff volume can be determined using the SCS hydrographic method, or other methods approved by the local jurisdiction.

When preparing the water budget, antecedent moisture conditions need to be considered during the months of the year when the ground may be saturated or frozen. For the SCS method the curve numbers (CN) should be adjusted as shown in Table 6.4.1 and Section 4.5. This requirement is applicable in climatic regions 1, 3, and 4 only. Climatic region 2 should use AMC II curve numbers throughout the year.

Table 6.4.1
Curve Number Adjustment for Antecedent Moisture Condition

Month	Antecedent Moisture Condition (AMC)	Minimum Runoff Curve Number (CN)
April-October	Normal (AMC = II)	See Table 4.5.2
November, March	Wet (AMC = III)	See Table 4.5.3
December-February	-	95

Water loss through evaporation from overland surface areas is normally not to be considered in the water budget, for the areas contributing runoff to the evaporation pond(s), due to the wide variation in evaporation rates which occur over these types of surfaces. The only reduction which can be considered in the analysis is runoff interception and surface infiltration, which are normally accounted for in the SCS curve members or rational coefficients.

Disposal is primarily through evaporation from the pond surface. Credit for infiltration through soils will not be considered in the water budget analysis in the absence of any site specific infiltration testing work being performed.

Geosynthetic or natural liners may be used to limit infiltration outflow volumes in areas where this is desired, or in locations where the seasonal water table will adversely impact the pond.

6.4.2 Other Design Considerations

When credit for infiltration is proposed, site characterization, testing, and reporting must be done in accordance with Section 6.3.

The design of the evaporative facility will need to evaluate the potential of groundwater seeping into the pond from the surrounding area for an unlined pond and evaluate the potential for groundwater mounding or uplift for a lined pond. A geotechnical evaluation should be performed, evaluating this potential negative impact, and, if needed, mitigation measures should be provided.

Sources of imported water need to be considered in the water budget design and calculations. Other sources may include irrigation, sewer septic tank/drainfield systems, natural springs, foundation drains, de-watering wells, etc. The geotechnical engineer shall address this issue in his/her report, and the designer should include any imported water in the water budget analysis.

The maximum water surface elevation permissible in the water budget is to be below the finish floor elevations of the surrounding buildings (existing or proposed). Privately owned parking lot areas, can be used for temporary storage of stormwater and considered in the water budget analysis. If ponding is proposed in parking lot areas, the maximum water depth should normally not exceed 1 foot.

If snow removal operations deposit snow into an evaporative system, this added factor must be considered in the water budget, especially if snow from another basin is put into the system. Temporary sediment ponds should to be included in the design, to prevent sediment-laden runoff from entering the pond and storm disposal system during construction.

6.4.3 Example Calculations

Spokane County's Public Works Department uses a spreadsheet for determining evaporation pond capacity requirements. The design is conservative and at the time of publication of this Manual the calculation process was being evaluated to identify whether changes should be considered.

The spreadsheet is included on the compact disc published with this Manual; it is also available on the Department of Ecology's website. Information on how the spreadsheet is set up and how to use it is provided below. The highlighted fields in the spreadsheet require input or consideration of the designer. An example of the spreadsheet input and results for a sample project site is shown in Table 6.4.2.

For this scenario, the overall drainage basin is 8.00 acres (on-site and off-site, Type B soils, with offsite being uphill and flowing onto the site). The example shown is for full evaporation without discharge via detention to a natural or existing drainage channel.

The example uses data from the nearest station with average monthly precipitation and pan evaporation data available. The monthly precipitation value is adjusted from the first to second column of the spreadsheet based upon the site location. Because evaporation data is collected using a shallow, metal evaporation pan that is fully exposed to sun and wind and affected by heat exchanges within the pan, the pan evaporation rate must be adjusted; the adjustment coefficient should be between 70% and 80%.

The total site area assumes that no off-site property is available for locating the pond; the spreadsheet automatically recalculates the area of the permeable portion of the basin as the pond size goes up or down. The starting point for the pond bottom area is generally to assume 25% of the total site for a typical commercial development.

The pond bottom perimeter is calculated as a square but can be entered manually if the pond perimeter is known. Remember that the perimeter will change if the pond bottom area is increased or decreased during design iterations. As the proposed pond bottom area changes, the portion of the impervious basin area attributed to the pond surface will also change.

The calculations are iterated for two or more years in order to see when the pond has reached a steady state: there should be a decrease the following year in the month with the largest storage (March in the example shown). The calculations assume that the pond contains a dead storage of the equivalent of the 100-year storm because typically, the only time a full-evaporation pond is needed is when there is no discharge point, no infiltrative capacity available, existing high groundwater, or potential for adjacent or downgradient property damage from additional stormwater being injected into the subsurface. The extra capacity provides emergency storage in the event that a site experiences above average total annual precipitation.

Some of the design criteria built into the spreadsheet are specific to Spokane County's Guidelines for Stormwater Management and may need to be adjusted for other local requirements. Among other requirements, Spokane County guidelines state that:

- For impervious surfaces such as roads, sidewalks and driveways, the AMC II CN is 98, and the AMC III CN is 99. From December through February, the assumption is that if the CN of 98 goes up to 99 during the wet months it will not revert to 98 during frozen ground conditions.
- During December through February, the CN for permeable surfaces is 95 regardless of the AMC II or III CNs, meant to approximate runoff from permeable surfaces during snowpack buildup and snowmelt.
- One foot of freeboard is needed above the maximum water surface elevation of the pond.

• **Table 6.4.2 -- Example spreadsheet calculations for sizing an evaporative pond at a site in the Spokane area**

Project :	EXAMPLE SITE IN SPOKANE AREA		
Plat / BSP / Proj No:	###	Engineer:	initials
Date:	8/10/2004		
Pond Bottom Area:		112,000	sq. ft.
Pond Bottom Perimeter:		1,339	ft
Pond Side Slopes:		3	: 1
Impervious Basin Size (Constant):		2.00	acres
Impervious Basin Size (Pond Area):		2.57	acres
Permeable Basin Size:		2.43	acres
Off-Site Upstream Basin:		1.00	acres
Total Basin Size:	8.00	8.00	acres
Mean Annual Prec. - Airport:		16.11	in
Mean Annual Prec. - Site:		19.70	in
Multiplier:		1.22	
100-Year, 24 Hour, Prec.:		2.70	in

Evaporative Pond to Accommodate 100% of Post-Developed Runoff Volume
(no infiltration allowed)

CONDITION: FULL CONTAINMENT

	AMC II Apr-Oct	AMC III Nov&Mar	--- Dec-Feb
Impervious CN:	98	99	99
Permeable CN:	61	78	95
Off-Site CN:	58	76	95
Impervious S:	0.20	0.10	0.10
Permeable S:	6.39	2.82	0.53
Off-Site S:	7.24	3.16	0.53

RESULTS:		
Pond Volume:	246,080	cu ft
Pond Depth:	2.20	ft
Add 1' freeboard:	3.20	ft

						INFLOW				OUTFLOW		STORAGE	POND DATA	
Month	Precip. (in)	Adjusted Precip. (in)	Impervious Runoff Depth (in)	Permeable Runoff Depth (in)	Off-Site Runoff Depth (in)	Impervious Runoff Volume (cu ft)	Permeable Runoff Volume (cu ft)	Off-Site Runoff Volume (cu ft)	NET Runoff Volume (cu ft)	Pan Evap. (in)	Evap. Vol. Out; 72% Adj. (cu ft)	Volume Stored in Pond (cu ft)	Pond Depth (ft)	Pond Capacity (%)
												20,878	0.19	8
Oct.	1.22	1.49	1.27	0.01	0.00	21,109	61	1	21,171	2.58	17,453	24,595	0.22	10
Nov.	2.02	2.47	2.35	0.77	0.68	39,043	6,777	2,456	48,276	0.92	6,231	66,640	0.59	26
Dec.	2.22	2.71	2.60	2.17	2.17	43,095	19,145	7,882	70,123	0.51	3,500	133,263	1.19	52
Jan.	2.05	2.51	2.39	1.97	1.97	39,651	17,368	7,151	64,169	0.61	4,274	193,157	1.72	76
Feb.	1.57	1.92	1.80	1.41	1.41	29,930	12,402	5,106	47,438	1.11	7,920	232,675	2.08	91
Mar.	**1.38**	**1.69**	**1.57**	**0.32**	**0.26**	**26,086**	**2,821**	**961**	**29,868**	**2.28**	**16,463**	**246,080**	**2.20**	**96**
Apr.	1.11	1.36	1.14	0.00	0.00	18,914	8	0	18,922	4.45	32,260	232,742	2.08	91
May	1.37	1.68	1.45	0.02	0.01	24,111	204	25	24,340	6.69	48,307	208,776	1.86	82
June	1.27	1.55	1.33	0.01	0.00	22,109	100	5	22,214	8.14	58,357	172,633	1.54	67
July	0.50	0.61	0.42	0.00	0.00	6,974	0	0	6,974	10.70	75,878	103,728	0.93	41
Aug.	0.60	0.73	0.54	0.00	0.00	8,881	0	0	8,881	9.42	65,405	47,205	0.42	18
Sept.	0.80	0.98	0.77	0.00	0.00	12,775	0	0	12,775	5.90	40,247	19,733	0.18	8
Oct.	1.22	1.49	1.27	0.01	0.00	21,109	61	1	21,171	2.58	17,447	23,456	0.21	9
Nov.	2.02	2.47	2.35	0.77	0.68	39,043	6,777	2,456	48,276	0.92	6,229	65,503	0.58	26
Dec.	2.22	2.71	2.60	2.17	2.17	43,095	19,145	7,882	70,123	0.51	3,499	132,127	1.18	52
Jan.	2.05	2.51	2.39	1.97	1.97	39,651	17,368	7,151	64,169	0.61	4,273	192,023	1.71	75
Feb.	1.57	1.92	1.80	1.41	1.41	29,930	12,402	5,106	47,438	1.11	7,918	231,543	2.07	91
Mar.	**1.38**	**1.69**	**1.57**	**0.32**	**0.26**	**26,086**	**2,821**	**961**	**29,868**	**2.28**	**16,457**	**244,954**	**2.19**	**96**
Apr.	1.11	1.36	1.14	0.00	0.00	18,914	8	0	18,922	4.45	32,249	231,627	2.07	91
May	1.37	1.68	1.45	0.02	0.01	24,111	204	25	24,340	6.69	48,291	207,677	1.85	81
June	1.27	1.55	1.33	0.01	0.00	22,109	100	5	22,214	8.14	58,338	171,552	1.53	67
July	0.50	0.61	0.42	0.00	0.00	6,974	0	0	6,974	10.70	75,853	102,673	0.92	40
Aug.	0.60	0.73	0.54	0.00	0.00	8,881	0	0	8,881	9.42	65,383	46,171	0.41	18
Sept.	0.80	0.98	0.77	0.00	0.00	12,775	0	0	12,775	5.90	40,234	18,712	0.17	7

6.5 Natural Dispersion

Natural dispersion attempts to minimize the hydrologic changes created by new impervious surfaces by restoring the natural drainage patterns of sheet flow and infiltration. There are three types of natural dispersion. They are:

- BMP F6.40 Concentrated Flow Dispersion
- BMP F6.41 Sheet Flow Dispersion
- BMP F6.42 Full Dispersion

BMP F6.40 Concentrated Flow Dispersion

Purpose and Definition

Dispersion of concentrated flows from driveways or other pavement through a vegetated pervious area attenuates peak flows by slowing entry of the runoff into the conveyance system, allows for some infiltration, and provides some water quality benefits. Flow dispersion is not subject to UIC regulations (see Chapter 5.6).

Applications and Limitations

- Any situation where concentrated flow can be dispersed through vegetation.
- Dispersion for driveways will generally only be effective for single-family residences on large lots and in rural short plats. Lots proposed by short plats in urban areas will generally be too small to provide effective dispersion of driveway runoff.
- Figure 6.5.1 shows two possible ways of spreading flows from steep driveways.

Design Guidelines

- A vegetated flowpath of at least 50 feet should be maintained between the discharge point and any property line, structure, steep slope, stream, lake, wetland, lake, or other impervious surface.
- A maximum of 700 square feet of impervious area may drain to each dispersion BMP.
- A pad of crushed rock (2 feet wide by 3 feet long by 6 inches deep) shall be placed at each discharge point.
- No erosion or flooding of downstream properties may result.
- Runoff discharged towards landslide hazard areas must be evaluated by a geotechnical engineer or qualified geologist. The discharge point shall not be placed on or above slopes greater than 6:1 or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval by the local jurisdiction.
- For sites with septic systems, the discharge point should be downgradient of the drainfield primary and reserve areas. This requirement may be waived by the local jurisdiction if site topography clearly prohibits flows from intersecting the drainfield.

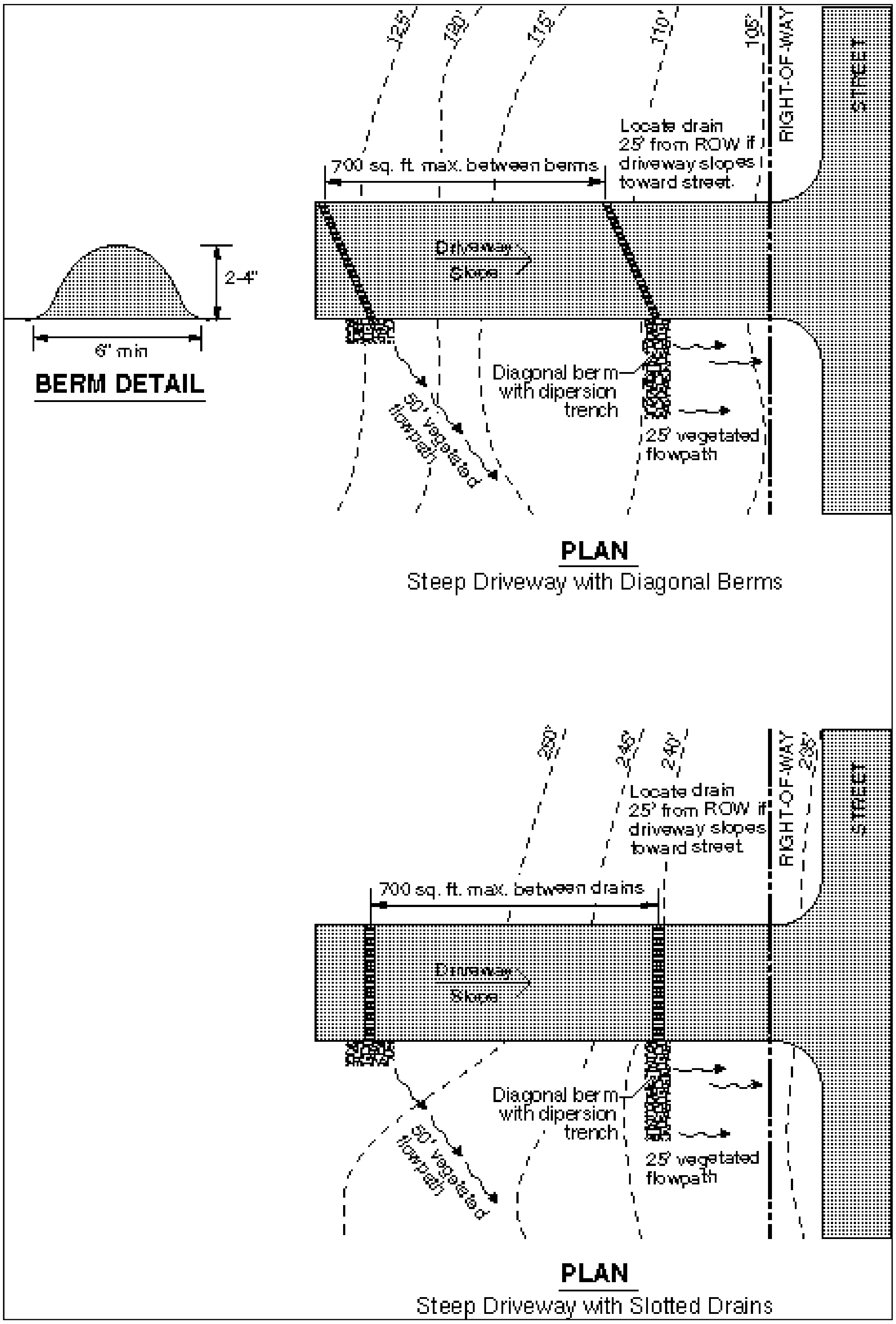


Figure 6.5.1 – Typical concentrated flow dispersion for steep driveways

BMP F6.41 Sheet Flow Dispersion

Purpose and Definition

Sheet flow dispersion is the simplest method of runoff control. This BMP can be used for any impervious or pervious surface that is graded so as to avoid concentrating flows. Because flows are already dispersed as they leave the surface, they need only traverse a narrow band of adjacent vegetation for effective attenuation and treatment. Sheet flow dispersion is not subject to UIC regulations (see Chapter 5.6).

Applications and Limitations

Flat or moderately sloping (<15% slope) impervious surfaces such as driveways, sport courts, patios, and roofs without gutters; sloping cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture; or any situation where concentration of flows can be avoided.

Design Guidelines

- See Figure 6.5.2 for details for driveways.
- A 2-foot-wide transition zone to discourage channeling should be provided between the edge of the driveway pavement and the downslope vegetation, or under building eaves. This may be an extension of sub-grade material (crushed rock), modular pavement, drain rock, or other material acceptable to the local jurisdiction.
- A vegetated buffer width of 10 feet of vegetation must be provided for up to 20 feet of width of paved or impervious surface. An additional 5 feet of width must be added for each additional 20 feet of width or fraction thereof.
- A vegetated buffer width of 25 feet of vegetation must be provided for up to 150 feet of contributing cleared area (i.e., bare soil, non-native landscaping, lawn, and/or pasture).
- Slopes within the 10- or 25-foot minimum flow path through vegetation should be no steeper than 8 percent. If this criterion cannot be met due to site constraints, the 10- or 25-foot flow path length must be increased 1.5 feet for each percent increase in slope above 8%.
- No erosion or flooding of downstream properties may result.
- Runoff discharge toward landslide hazard areas must be evaluated by a geotechnical engineer or a qualified geologist. The discharge point may not be placed on or above slopes greater than 20% or above erosion hazard areas without evaluation by a geotechnical engineer or qualified geologist and approval by the local jurisdiction.
- For sites with septic systems, the discharge point must be downgradient of the drain field primary and reserve areas. This requirement may be waived by the local jurisdiction if site topography clearly prohibits flows from intersecting the drain field.

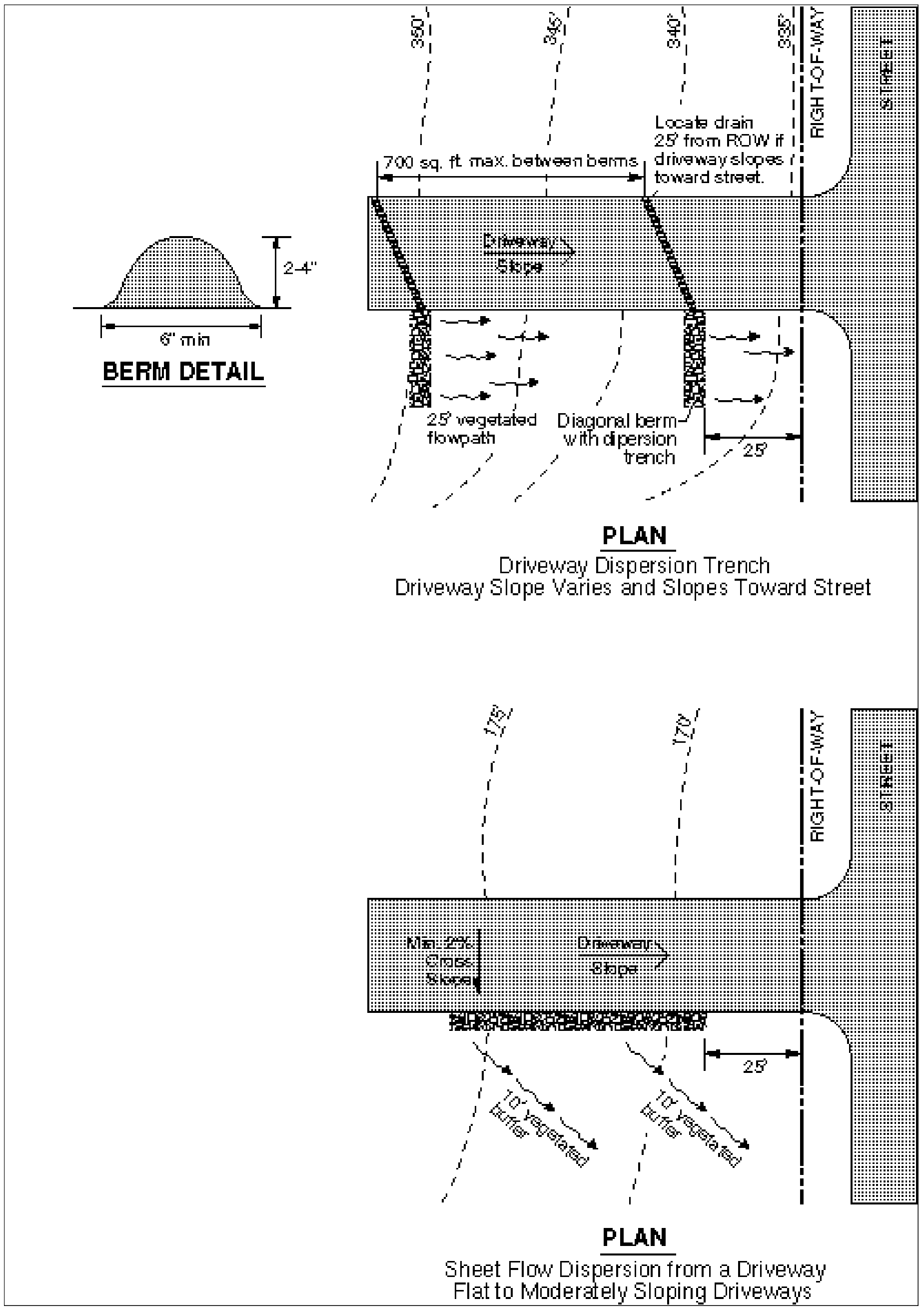


Figure 6.5.2 – Sheet flow dispersion for driveways

BMP F6.42 Full Dispersion

Purpose and Definition

This BMP allows for "fully dispersing" runoff from impervious surfaces and cleared areas of commercial and residential development sites that protect a portion of the site (or for large sites, a portion of an area within a sub-basin drainage on the site) in a natural, native vegetation cover condition. Natural vegetation is preserved and maintained in accordance with guidelines. Runoff from roofs, driveways, and roads within the development is dispersed within the site by utilizing the areas of preserved vegetation.

This BMP is primarily intended for areas of new development. A sliding scale for the amount of preserved vegetated area is provided to allow application to other sites. A dispersion BMP for road projects may be developed and included in the next revised version of the WSDOT *Highway Runoff Manual*.

Full dispersion is not subject to UIC regulations. However, Figure 6.5.3 shows a standard dispersion trench which is subject to UIC regulations; see Chapter 5.6.

Applications and Limitations

- Up to 10% of the site that is impervious surface can be rendered non-effective impervious area by dispersing runoff from it into the native vegetation area. Any additional impervious areas (this BMP recommends limiting additional impervious areas to not more than another 10% for rural areas) are considered effective impervious surfaces with the exception of roofs served by drywells.
- Types of development that retain a percentage of the site (or for large sites, a portion of an area within a sub-basin drainage on the site) in a natural forested or other native vegetation cover condition may also use these BMPs to avoid triggering the flow control facility requirement or to minimize its use at the site.

Design Guidelines

Impervious areas of residential developments can meet treatment and flow control requirements by distributing runoff into native vegetation areas that meet the limitations and design guidelines below if the ratio of impervious area to native vegetation area does not exceed 15%. Vegetation must be preserved and maintained according to the following requirements:

- The preserved area should be situated to minimize the clearing of existing natural vegetative cover, to maximize the preservation of wetlands, and to buffer stream corridors.
- The preserved area should be placed in a separate tract or protected through recorded easements for individual lots.

- If feasible, the preserved area should be located downslope from the building sites, since flow control and water quality are enhanced by flow dispersion through undisturbed soils and native vegetation.
- The preserved area should be shown on all property maps and should be clearly marked during clearing and construction on the site.
- Vegetation and trees should not be removed from the natural growth retention area, except for the removal of dangerous and diseased trees.

The requirement operates on a "sliding scale" comparing the percentage of the site with undisturbed native vegetation to the percentage of the site with impervious surface that drains into those areas of preserved native vegetation:

% of site with impervious surface that drains into native vegetation area	% of site with undisturbed native vegetation
10.0	65
9.0	60
8.25	55
7.5	50
6.75	45
6.0	40
5.25	35
4.5	30
3.75	25
3.0	20

Roof Downspouts: Roof surfaces that are connected to drywells are considered "fully dispersed" provided that they are designed according to local requirements. Otherwise, the roof runoff is assumed to run into the street, and that volume must be added to the volume dispersed in the roadway dispersion component of this BMP.

Driveway Dispersion: Driveway surfaces are considered to be "fully dispersed" if the site meets the required ratio of impervious surfaces to preserved native vegetation above, and if they comply with the driveway dispersion BMPs – BMP T6.40 and BMP T6.41 - and have flow paths through native vegetation exceeding 100 feet. This also holds true for any driveway surfaces that comply with the roadway dispersion BMPs described below.

Roadway Dispersion BMPs: Roadway surfaces are considered to be "fully dispersed" if the site meets the required ratio of impervious surfaces to preserved native vegetation above, and if they comply with the following dispersion requirements:

- Roadway runoff dispersion is allowed only on rural neighborhood collectors and local access streets. To the extent feasible, driveways should be dispersed to the same standards as roadways to ensure adequate water quality protection of downstream resources.

- The road section shall be designed to minimize collection and concentration of roadway runoff. Sheet flow over roadway fill slopes (i.e., where roadway subgrade is above adjacent right-of-way) should be used wherever possible to avoid concentration.
- When it is necessary to collect and concentrate runoff from the roadway and adjacent upstream areas (e.g., in a ditch on a cut slope), concentrated flows shall be incrementally discharged from the ditch via cross culverts or at the ends of cut sections. These incremental discharges of newly concentrated flows shall not exceed 0.5 cfs at any one discharge point from a ditch for the 100-year runoff event. Where flows at a particular ditch discharge point were already concentrated under existing site conditions (e.g., in a natural channel that crosses the roadway alignment), the 0.5-cfs limit would be in addition to the existing concentrated peak flows.
- Ditch discharge points with up to 0.2 cfs discharge for the peak 100-year flow shall use rock pads or dispersion trenches to disperse flows. Ditch discharge points with between 0.2 and 0.5 cfs discharge for the 100-year peak flow shall use only dispersion trenches to disperse flows.
- Dispersion trenches shall be designed to accept surface flows (free discharge) from a pipe, culvert, or ditch end, shall be aligned perpendicular to the flowpath, and shall be minimum 2 feet by 2 feet in section, 50 feet in length, filled with ¾-inch to 1½-inch washed rock, and provided with a level notched grade board (see Figure 6.5.3). Manifolds may be used to split flows up to 2 cfs discharge for the 100-year peak flow between up to 4 trenches. Dispersion trenches shall have a minimum spacing of 50 feet.
- After being dispersed with rock pads or trenches, flows from ditch discharge points must traverse a minimum of 100 feet of undisturbed native vegetation before leaving the project site, or entering an existing onsite channel carrying existing concentrated flows across the road alignment.
  Note: In order to provide the 100-foot flowpath length to an existing channel, some roadway runoff may unavoidably enter the channel undispersed. Also note that water quality treatment may be waived for roadway runoff dispersed through 100 feet of undisturbed native vegetation.
- Flowpaths from adjacent discharge points must not intersect within the 100-foot flowpath lengths, and dispersed flow from a discharge point must not be intercepted by another discharge point. To enhance the flow control and water quality effects of dispersion, the flowpath shall not exceed 15% slope, and shall be located within designated open space.
  Note: Runoff may be conveyed to an area meeting these flowpath criteria.
- Ditch discharge points shall be located a minimum of 100 feet upgradient of steep slopes (i.e., slopes steeper than 40%), wetlands, and streams.

- Where the local jurisdiction determines there is a potential for significant adverse impacts downstream (e.g., erosive steep slopes or existing downstream drainage problems), dispersion of roadway runoff may not be allowed, or other measures may be required.

Cleared Area Dispersion BMPs: The runoff from cleared areas that are comprised of bare soil, non-native landscaping, lawn, and/or pasture is considered to be "fully dispersed" if it is dispersed through at least 25 feet of native vegetation in accordance with the following criteria:

- The contributing flowpath of cleared area being dispersed must be no more than 150 feet, and
- Slopes within the 25-foot minimum flowpath through native vegetation should be no steeper than 8%. If this criterion can not be met due to site constraints, the 25-foot flowpath length must be increased 1.5 feet for each percent increase in slope above 8%.

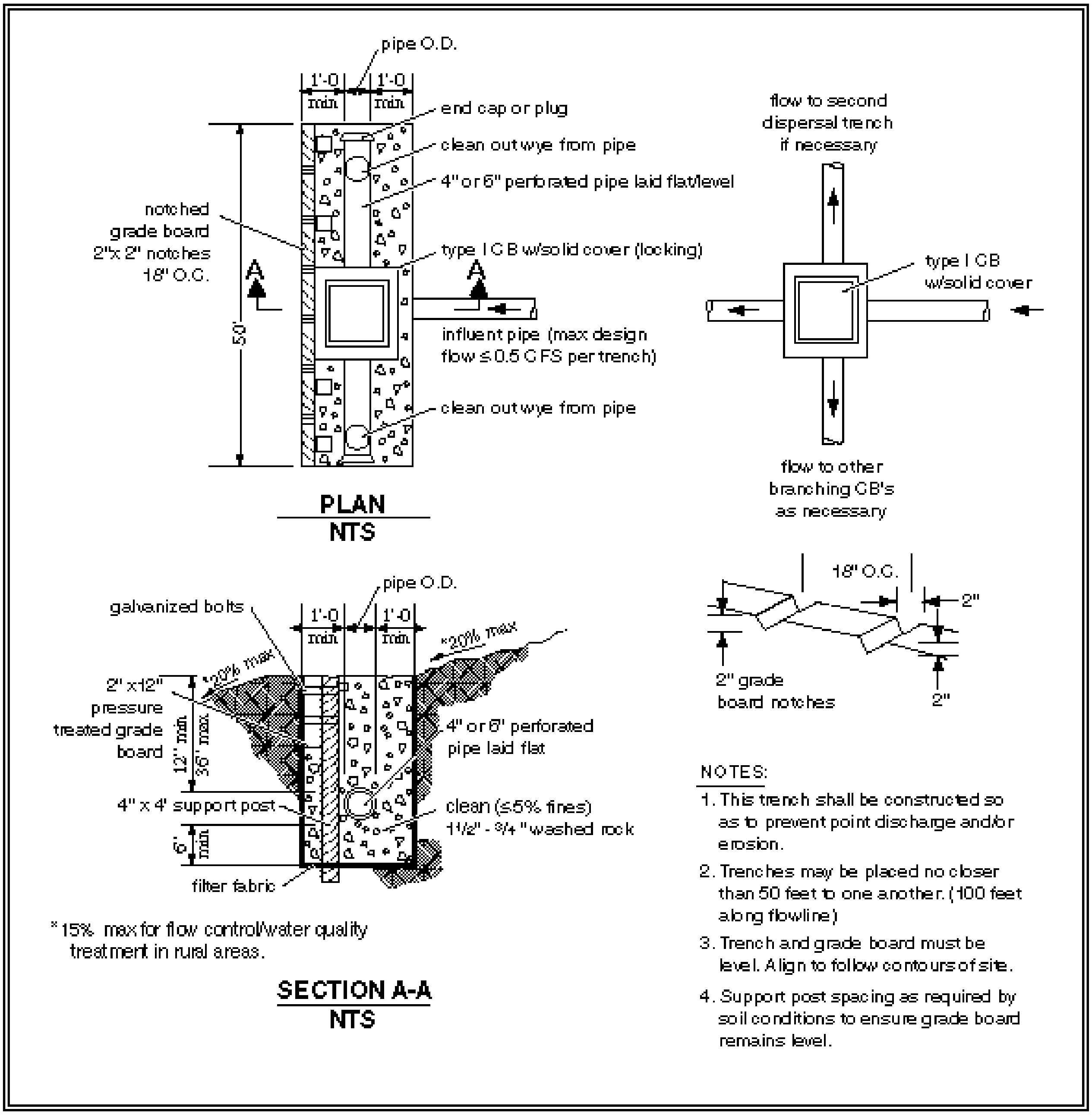


Figure 6.5.3 – Standard dispersion trench with notched grade board

Appendix 6A – Maintenance Requirements

Maintenance Requirements for Detention Ponds

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
General	Trash & Debris	**Any trash and debris which exceed 5 cubic feet per 1,000 square feet (this is about equal to the amount of trash it would take to fill up one standard size garbage can). In general, there should be no visual evidence of dumping.** If less than threshold all trash and debris will be removed as part of next scheduled maintenance.	Trash and debris cleared from site.
	Poisonous Vegetation and noxious weeds	Any poisonous or nuisance vegetation which may constitute a hazard to maintenance personnel or the public. Any evidence of noxious weeds as defined by State or local regulations. (Apply requirements of adopted Integrated Pest Management (IPM) policies for the use of herbicides).	No danger of poisonous vegetation where maintenance personnel or the public might normally be. (Coordinate with local health department) Complete eradication of noxious weeds may not be possible. Compliance with State or local eradication policies required
	Contaminants and Pollution	Any evidence of oil, gasoline, contaminants or other pollutants (Coordinate removal/cleanup with local water quality response agency).	No contaminants or pollutants present.
	Rodent Holes	Any evidence of rodent holes if facility is acting as a dam or berm, or any evidence of water piping through dam or berm via rodent holes.	Rodents destroyed and dam or berm repaired. (Coordinate with local health department and Ecology Dam Safety Office if pone exceeds 10 acre feet)
	Beaver Dams	Dam results in change or function of the facility.	Facility is returned to design function. (Coordinate trapping of beavers and removal of dams with appropriate permitting agencies)
	Insects	When insects such as wasps and hornets interfere with maintenance activities.	Insects destroyed or removed from site. Apply insecticides in compliance with adopted IPM policies.

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
	Tree Growth and Hazard Trees	Tree growth does not allow maintenance access or interferes with maintenance activity (i.e., slope mowing, silt removal, vactoring, or equipment movements). If trees are not interfering with access or maintenance, do not remove If dead, diseased, or dying trees are identified (Use a certified Arborist to determine health of tree or removal requirements)	Trees do not hinder maintenance activities. Harvested trees should be recycled into mulch or other beneficial uses (e.g., alders for firewood). Remove hazard trees
Side Slopes of Pond	Erosion	Eroded damage over 2 inches deep where cause of damage is still present or where there is potential for continued erosion. Any erosion observed on a compacted berm embankment.	Slopes should be stabilized using appropriate erosion control measure(s); e.g., rock reinforcement, planting of grass, compaction. If erosion is occurring on compacted berms a licensed civil engineer should be consulted to resolve source of erosion.
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the facility.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (If Applicable)	Liner is visible and has more than three 1/4-inch holes in it.	Liner repaired or replaced. Liner is fully covered.
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed civil engineer should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.

Maintenance Component	Defect	Conditions When Maintenance Is Needed	Results Expected When Maintenance Is Performed
Emergency Overflow/Spill way and Berms over 4 feet in height	Tree Growth	Tree growth on emergency spillways create blockage problems and may cause failure of the berm due to uncontrolled overtopping. Tree growth on berms over 4 feet in height may lead to piping through the berm which could lead to failure of the berm.	Trees should be removed. If root system is small (base less than 4 inches) the root system may be left in place. Otherwise the roots should be removed and the berm restored. A licensed civil engineer should be consulted for proper berm/spillway restoration.
	Piping	Discernible water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
Emergency Overflow/Spill way	Emergency Overflow/ Spillway	Only one layer of rock exists above native soil in area five square feet or larger, or any exposure of native soil at the top of out flow path of spillway. (Rip-rap on inside slopes need not be replaced.)	Rocks and pad depth are restored to design standards.
	Erosion	See "Side slopes of Pond"	

Maintenance Requirements for Detention Vaults/Tanks

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
Storage Area	Plugged Air Vents	One-half of the cross section of a vent is blocked at any point or the vent is damaged.	Vents open and functioning.
	Debris and Sediment	Accumulated sediment depth exceeds 10% of the diameter of the storage area for 1/2 length of storage vault or any point depth exceeds 15% of diameter. (Example: 72-inch storage tank would require cleaning when sediment reaches depth of 7 inches for more than 1/2 length of tank.)	All sediment and debris removed from storage area.
	Joints Between Tank/Pipe Section	Any openings or voids allowing material to be transported into facility. (Will require engineering analysis to determine structural stability).	All joint between tank/pipe sections are sealed.
	Tank Pipe Bent Out of Shape	Any part of tank/pipe is bent out of shape more than 10% of its design shape. (Review required by engineer to determine structural stability).	Tank/pipe repaired or replaced to design.
	Vault Structure Includes Cracks in Wall, Bottom, Damage to Frame and/or Top Slab	Cracks wider than 1/2-inch and any evidence of soil particles entering the structure through the cracks, or maintenance/inspection personnel determines that the vault is not structurally sound.	Vault replaced or repaired to design specifications and is structurally sound.
		Cracks wider than 1/2-inch at the joint of any inlet/outlet pipe or any evidence of soil particles entering the vault through the walls.	No cracks more than 1/4-inch wide at the joint of the inlet/outlet pipe.
Manhole	Cover Not in Place	Cover is missing or only partially in place. Any open manhole requires maintenance.	Manhole is closed.
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread (may not apply to self-locking lids).	Mechanism opens with proper tools.

Maintenance Component	Defect	Conditions When Maintenance is Needed	Results Expected When Maintenance is Performed
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. Intent is to keep cover from sealing off access to maintenance.	Cover can be removed and reinstalled by one maintenance person.
	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, misalignment, not securely attached to structure wall, rust, or cracks.	Ladder meets design standards. Allows maintenance person safe access.

Maintenance of Control Structures

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash and Debris (Includes Sediment)	Material exceeds 25% of sump depth or 1 foot below orifice plate.	Control structure orifice is not blocked. All trash and debris removed.
	Structural Damage	Structure is not securely attached to manhole wall.	Structure securely attached to wall and outlet pipe.
		Structure is not in upright position (allow up to 10% from plumb).	Structure in correct position.
		Connections to outlet pipe are not watertight and show signs of rust.	Connections to outlet pipe are water tight; structure repaired or replaced and works as designed.
		Any holes--other than designed holes--in the structure.	Structure has no holes other than designed holes.
Cleanout Gate	Damaged or Missing	Cleanout gate is not watertight or is missing.	Gate is watertight and works as designed.
		Gate cannot be moved up and down by one maintenance person.	Gate moves up and down easily and is watertight.
		Chain/rod leading to gate is missing or damaged.	Chain is in place and works as designed.
		Gate is rusted over 50% of its surface area.	Gate is repaired or replaced to meet design standards.
Orifice Plate	Damaged or Missing	Control device is not working properly due to missing, out of place, or bent orifice plate.	Plate is in place and works as designed.
	Obstructions	Any trash, debris, sediment, or vegetation blocking the plate.	Plate is free of all obstructions and works as designed.
Overflow Pipe	Obstructions	Any trash or debris blocking (or having the potential of blocking) the overflow pipe.	Pipe is free of all obstructions and works as designed.

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
Manhole	See requirements for vaults/tanks		
General	Trash & Debris	Trash or debris which is located immediately in front of the catch basin opening or is blocking inletting capacity of the basin by more than 10%.	No Trash or debris located immediately in front of catch basin or on grate opening.
		Trash or debris (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of six inches clearance from the debris surface to the invert of the lowest pipe.	No trash or debris in the catch basin.
		Trash or debris in any inlet or outlet pipe blocking more than 1/3 of its height.	Inlet and outlet pipes free of trash or debris.
		Dead animals or vegetation that could generate odors that could cause complaints or dangerous gases (e.g., methane).	No dead animals or vegetation present within the catch basin.
	Sediment	Sediment (in the basin) that exceeds 60 percent of the sump depth as measured from the bottom of basin to invert of the lowest pipe into or out of the basin, but in no case less than a minimum of 6 inches clearance from the sediment surface to the invert of the lowest pipe. Measured from the bottom of basin to invert of the lowest pipe into or out of the basin.	No sediment in the catch basin
	Structure Damage to Frame and/or Top Slab	Top slab has holes larger than 2 square inches or cracks wider than 1/4 inch (Intent is to make sure no material is running into basin).	Top slab is free of holes and cracks.
		Frame not sitting flush on top slab, i.e., separation of more than 3/4 inch of the frame from the top slab. Frame not securely attached	Frame is sitting flush on the riser rings or top slab and firmly attached.
	Fractures or Cracks in	Maintenance person judges that structure is unsound.	Basin replaced or repaired to design standards.

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
	Basin Walls/ Bottom	Grout fillet has separated or cracked wider than 1/2 inch and longer than 1 foot at the joint of any inlet/outlet pipe or any evidence of soil particles entering catch basin through cracks.	Pipe is regrouted and secure at basin wall.
	Settlement/ Misalignment	If failure of basin has created a safety, function, or design problem.	Basin replaced or repaired to design standards.
	Vegetation	Vegetation growing across and blocking more than 10% of the basin opening.	No vegetation blocking opening to basin.
		Vegetation growing in inlet/outlet pipe joints that is more than six inches tall and less than six inches apart.	No vegetation or root growth present.
	Contamination and Pollution	See "Detention Ponds"	No pollution present.
Catch Basin Cover	Cover Not in Place	Cover is missing or only partially in place. Any open catch basin requires maintenance.	Catch basin cover is closed
	Locking Mechanism Not Working	Mechanism cannot be opened by one maintenance person with proper tools. Bolts into frame have less than 1/2 inch of thread.	Mechanism opens with proper tools.
	Cover Difficult to Remove	One maintenance person cannot remove lid after applying normal lifting pressure. (Intent is keep cover from sealing off access to maintenance.)	Cover can be removed by one maintenance person.
Ladder	Ladder Rungs Unsafe	Ladder is unsafe due to missing rungs, not securely attached to basin wall, misalignment, rust, cracks, or sharp edges.	Ladder meets design standards and allows maintenance person safe access.
Metal Grates (if applicable)	Grate opening Unsafe	Grate with opening wider than 7/8 inch.	Grate opening meets design standards.
	Trash and Debris	Trash and debris that is blocking more than 20% of grate surface inletting capacity.	Grate free of trash and debris.
	Damaged or Missing.	Grate missing or broken member(s) of the grate.	Grate is in place and meets design standards.

Maintenance Requirements for Drywells

The structural life of a drywell is approximately 20 years, although hydraulic failure could potentially occur at anytime. Drywell performance is dependent upon proper installation, regularly scheduled maintenance and contaminants reaching swale and drywell facility. The following schedule is recommended as a guide; actual schedule may need to be varied based upon observed performance.

Maintenance interval	***Description of maintenance to be performed***
every 3 months	Visually inspect.
every 6 months	Remove debris and sediment.
annually	Check for structural damage.
Whichever is more frequent: above schedule or below observed events:	
following substantial (>24 hr) rainfall event	If possible, observe facilities in operation during the rainfall event. Aim to identify and correct problem prior to failure.
following intense but short duration event	
following snowmelt event	It is especially important to observe the facilities if the melt occurred concurrently with frozen ground conditions.

<u>DEFINITIONS OF MAINTENANCE TASKS</u>:

1) **Visual Inspection**: Ensure metal grate and drywell are free of debris and obstructions. Remove any debris from on top of or around drywell and grate. Remove grate and inspect drywell for debris and sediment build-up in the barrel. Debris needs to be removed immediately, if possible. Sediment needs to be cleaned out before depth reaches the lowest row of slots providing outflow from drywell barrel.

   Anytime that standing water is noticed in a drywell or swale more than 24 hours after an event has ceased, a visual inspection is warranted. When standing water is observed, the inspector should be aware of any signs of illicit discharge. If any of the following are observed, in addition to the sod and topsoil being affected and requiring replacement, if it is evident that discharge was made directly into the drywell, the drywell and affected surrounding drain rock must be replaced as soon as possible: oil sheen, spilled paint, burned area due to battery acid, multi-colored appearance of antifreeze, brown to black fuel oil, or any other materials that may be deemed deleterious to water quality. Sod, topsoil and drain rock removed must be handled and disposed of in a manner consistent with a hazardous material.

2) **Remove Debris and Sediment:** Remove any large debris that would interfere with the vactoring (suction removal) of the drywell. Sediment must be completely suctioned out of the drywell barrel. Care should be taken to note the depth of the sediment. If it appears that the sediment is increasing with depth at each inspection, this may be a sign that the swale is not functioning properly; stormwater may be ponding and spilling, carrying sediment laden stormwater into the drywell, rather than infiltrating at the design rate.

3) **Check for Structural Damage:** Inspect metal frame and grate, adjustment rings, mortar or any other visible parts of the drywell structure. The metal frame and grate should sit flush on the top ring. Any separation of ¾ inch of greater must be adjusted and repaired. The drywell should be replaced or repaired to design standards if it has settled more than 2 inches or if standing water fails to drain out of the barrel slots. Adjustment rings should be free of cracks. Crack repair should adhere be performed when:

location of crack	***maximum width of crack***
top ring of drywell	¼ inch
drywell barrel	½ inch and longer than 3 feet
drywell floor	½ inch and longer than 1 foot

   It should be noted that any crack, regardless of location or width, in which sediment is observed, needs to be repaired as soon as possible. Cracks should be repaired with mortar similar to that used between the adjustment rings. Mortar or grout should be waterproof and of the non-shrink variety.

Maintenance Requirements for Infiltration Ponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash & Debris	See "Detention Ponds".	See "Detention Ponds".
	Poisonous/Noxious Vegetation	See "Detention Ponds".	See "Detention Ponds".
	Contaminants and Pollution	See "Detention Ponds".	See "Detention Ponds".
	Rodent Holes	See "Detention Ponds".	See "Detention Ponds".
Storage Area	Sediment	Water ponding in infiltration pond after rainfall ceases and appropriate time allowed for infiltration. (A percolation test pit or test of facility indicates facility is only working at 90% of its designed capabilities. If two inches or more sediment is present, remove).	Sediment is removed and/or facility is cleaned so that infiltration system works according to design.
Filter Bags (if applicable)	Filled with Sediment and Debris	Sediment and debris fill bag more than 1/2 full.	Filter bag is replaced or system is redesigned.
Rock Filters	Sediment and Debris	By visual inspection, little or no water flows through filter during heavy rain storms.	Gravel in rock filter is replaced.
Side Slopes of Pond	Erosion	See "Detention Ponds".	See "Detention Ponds".
Emergency Overflow Spillway and Berms over 4 feet in height.	Tree Growth	See "Detention Ponds".	See "Detention Ponds".
	Piping	See "Detention Ponds".	See "Detention Ponds".
Emergency Overflow Spillway	Rock Missing	See "Detention Ponds".	See "Detention Ponds".
	Erosion	See "Detention Ponds".	See "Detention Ponds".
Pre-settling Ponds and Vaults	Facility or sump filled with Sediment and/or debris	6" or designed sediment trap depth of sediment.	Sediment is removed.

Maintenance Requirements for Evaporation Ponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General	Trash & Debris	See "Detention Ponds".	See "Detention Ponds".
	Poisonous/Noxious Vegetation	See "Detention Ponds".	See "Detention Ponds".
	Contaminants and Pollution	See "Detention Ponds".	See "Detention Ponds".
	Rodent Holes	See "Detention Ponds".	See "Detention Ponds".
Side Slopes of Pond	Erosion	See "Detention Ponds".	See "Detention Ponds".
Storage Area	Sediment	Accumulated sediment that exceeds 10% of the designed pond depth unless otherwise specified or affects inletting or outletting condition of the facility.	Sediment cleaned out to designed pond shape and depth; pond reseeded if necessary to control erosion.
	Liner (If Applicable)	Liner is visible and has more than three 1/4-inch holes in it.	Liner repaired or replaced. Liner is fully covered.
Pond Berms (Dikes)	Settlements	Any part of berm which has settled 4 inches lower than the design elevation. If settlement is apparent, measure berm to determine amount of settlement. Settling can be an indication of more severe problems with the berm or outlet works. A licensed civil engineer should be consulted to determine the source of the settlement.	Dike is built back to the design elevation.
	Piping	Discernable water flow through pond berm. Ongoing erosion with potential for erosion to continue. (Recommend a Goethechnical engineer be called in to inspect and evaluate condition and recommend repair of condition.	Piping eliminated. Erosion potential resolved.
General	Inlet Pipe	Inlet pipe clogged with sediment and/or debris material.	No clogging or blockage in the inlet and outlet piping.
	Oil Sheen on Water	Prevalent and visible oil sheen.	Oil removed from water using oil-absorbent pads or vactor truck. Source of oil located and corrected. If chronic low levels of oil persist, plant wetland plants such as Juncus effusus (soft rush) which can uptake small concentrations of oil.
	Erosion	Erosion of the pond's side slopes and/or scouring of the pond bottom, that exceeds 6-inches, or where continued erosion is prevalent.	Slopes stabilized using proper erosion control measures and repair methods.
	Overflow Spillway	Rock is missing and soil is exposed at top of spillway or outside slope.	Rocks replaced to specifications.

Maintenance Requirements for Evaporation Ponds

Maintenance Component	Defect	Condition When Maintenance is Needed	Results Expected When Maintenance is Performed
General (cont'd)	Snow	Snow removal operations deposit snow into evaporative system	This added factor must be considered in the water budget, especially if snow from another basin is put into the system. Temporary sediment ponds should be included in the design, to prevent sediment-laden runoff from entering the pond and storm disposal system during construction.

Appendix 6B – Storm Drainage Design Guideline for Site Characterization

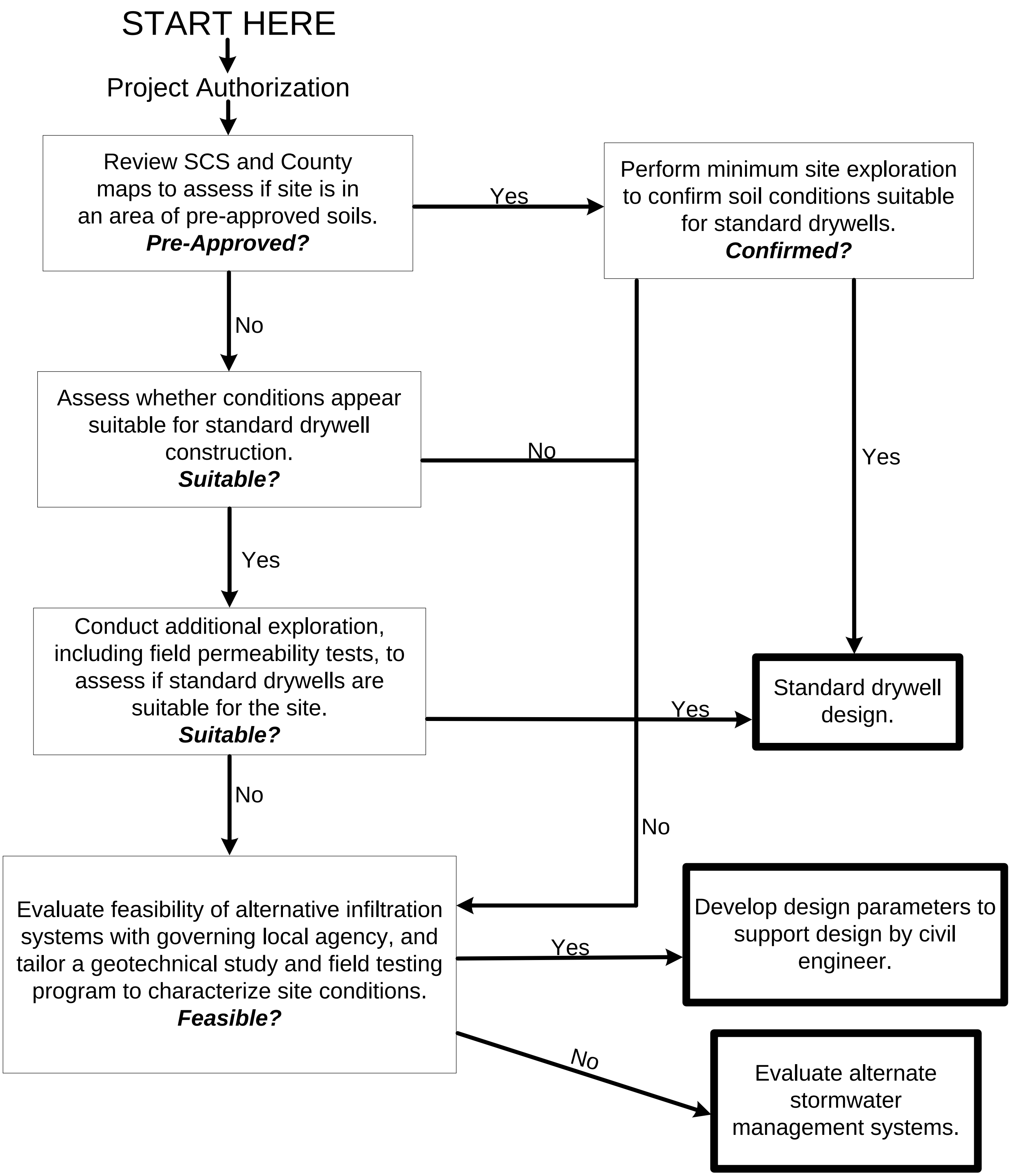
6B.1 Storm Drainage Design Guideline for Site Characterization

Geotechnical site characterization should be conducted to demonstrate the site's general suitability for on-site storm water disposal. The scope of the investigation should consist of, but not be limited to, the following elements:

1. Review applicable geologic maps of the site area, to identify any site conditions that can impact the use of storm drainage disposal systems. This may include outcrops, borrow pits, or existing ground water conditions.
2. Site explorations should consist of a minimum of three exploratory test pits or borings on the site and specifically in the planned disposal area. The explorations should extend at least 5 feet below the bottom of the proposed disposal facility. Deeper site exploration (10 to 50 feet) may be needed if well logs are not available.
3. Samples recovered from the site exploration work may be tested to assess gradational characteristics to help verify the soil classification for comparison with the mapped soil unit.
4. Include a surface reconnaissance of surrounding properties, particularly in the anticipated down-gradient ground water flow direction, to assess potential impact of additional ground water.
5. Perform laboratory testing to determine Unified Soil Classification Group Symbol and Group Name of the site soils.
6. Provide a summary report, describing the results of the work. Include a vicinity map, an exploration site plan, and laboratory test results. Include information regarding the depth to ground water and the presence of any limiting layers which may control ground water flow. Consider feasibility and limitations for on-site disposal. Include information on how the field permeability testing was performed and the assumptions made for determining the recommended infiltration rate. The report shall be prepared under the direction of a licensed professional civil engineer or geotechnical engineer and appropriately signed and sealed.

Note: The following figure and subsequent sections of this Appendix are taken from Spokane County Public Works' guidance for infiltration facilities. The information was current at the time of publication of this manual but may be updated.

Drywell Site Investigation Flow Chart



6B.2 Required Minimum Permeability for Use with Standard Drywell Practice

Spokane County Standard Type "A" or Type "B" drywells discharging at assumed rates of 0.3 cfs and 1.0 cfs, respectively, are allowed in soil groups other than Springdale, Garrison, Bonner, Hagen, Bong, Phoebe, and Marble provided the other standard drywell practice conditions are met, and the soil surrounding the drywell has a minimum permeability of 2.5 X 10^{-2} cm/s when tested in accordance with the field procedures outlined in this appendix.

Derivation of Minimum Permeability ("k") Value

This minimum required value is based upon modeling the drywell as a reverse well and applying an equation presented in USBR Test Procedure 7300-89 that relates outflow rate from an injection well under constant head conditions to soil permeability and other well geometric properties.

The derivation of this rate is presented on the following page of this appendix.

Please note that permeability "k" is used in the context of Darcy's Equation that describes flow through porous media:

$$Q = k * i * A$$

where: Q = Flow Rate in units of Volume/Time
k = Permeability in units of Length/Time
i = Hydraulic Gradient in units of Length/Length
A = Cross sectional area of flow in units of Length Squared

Also please note the difference between permeability "k" as described above and the soil infiltration rate "I". Within the context of this appendix, infiltration rate "I", is used to indicate a volume flow rate moving across a surface boundary having an area "A" (i.e. cfs / square foot).

2.5 X IO^{-2} cm/s Threshold Permeability Criteria Derivation

Basis for 2.5 X IO^{-2} cm/s minimum permeability criteria for standard drywells. Reference: "Performing Field Permeability Testing by the Well Permeameter Method" USBR Procedure 7300-89.

Given: Wetted perimeter of Type B standard drywell with 10-foot bore depth is about 600 square feet, (per Spokane County calculation 'circa 1992).

USBR Equation for Condition I (thickness of unsaturated strata greater than 3H, where H is the height of the water in the drywell).

The design equation is:

$$k = \frac{q}{2\pi H^2}\left(Ln\left[\frac{H}{r} + \sqrt{\left(\frac{H}{r}\right)^2 + 1} \right] - \frac{\sqrt{1 + \left(\frac{H}{r}\right)^2}}{H/r} + \frac{1}{H/r} \right)$$

The design equation is solved for the permeability (k) required for a constant inflow (q) of 1 cfs. Geometric parameters required include H and r. A standard Type B drywell installation, with an inverted conical envelope of drainage gravel provides approximately 600SF of side slope infiltration area. An equivalent cylindrical surface, having a side area of 600SF and a 10 ft. depth, would require an effective radius (r) of about 9.5 ft.

Using these parameters, the minimum required k for q = 1 cfs is therefore:
7.8×10^{-4} ft/sec = 2.4×10^{-2} cm/sec

6B.3 Recommended Field Test Procedures

Four standard field test methods are discussed in this section:

- Borehole methods, for determining permeability,
- Test pit methods, for determining permeability,
- Single-ring infiltrometer, for determining soil infiltration rate, and
- Constant head conditions, for determining outflow rate.

Estimating Field Permeability of Soil-in-Place Using Borehole Methods

(February 6, 1996)

Applicability

This test method is applicable for determining permeabilities for use in the design of standard and non-standard systems utilizing drywells. Note: Design deviation is required for all non-standard subsurface disposal systems.

Method

1) Using a hollow-stem. auger, advance a 6-inch-diameter or greater borehole to a depth of 2 to 5 feet below the anticipated elevation of the proposed drainage structure. Use care not to contaminate the sides of the hole with fines.
2) Install a slotted pipe or well-screen into the hole having a minimum diameter of 2 inches and a minimum 20% open area through the hollow-stem portion of the auger-string. Install the pipe as nearly as is practical to the bottom of the hole. Wrapping the pipe with a highly porous, non-woven , geotextile fabric is an allowable practice.

3) During auger removal, install a gravel-pack of uniform, clean, dry, pervious fine gravel around the slotted pipe. Omission of this step is an allowable practice. However, calculations for permeability must be based upon the original diameter of the borehole, therefore omission of the gravel pack is not recommended.

4) Introduce clean water near the bottom of the hole through the slotted pipe using an in-line, commercially available, flow meter. Prior to the test, field check the accuracy of the flow meter using a suitable container of known volume (i.e. 5 gallon bucket, etc).

5) Raise the water level in the hole until a level consistent with the operating head anticipated in the proposed drainage structure is achieved. Based upon the soil permeability, the subsurface soil profile, and the water supply system available, head levels lower than those anticipated in the drainage structure are permitted.

6) Adjust the flow rate as needed to maintain the constant head level in the hole. Minimum required test time is I hour.

7) Monitor and record the flow rate required to maintain the constant-head level at appropriate intervals. In no case shall the interval exceed 10 minutes in length.

8) Continue maintaining the constant head until a stabilized flow rate has been achieved. Consider the flow rate stable when the incremental flow rate required to maintain the head does not vary by more than about 5% between increments. The intent of this section is to achieve a relatively steady-state flow condition between the minimum I hour test time and a maximum test time of 1+1/2 hours. At the discretion of the on-site engineer or engineering technician, the test may be extended beyond the 1+1/2 hour maximum.

9) Upon completion of the constant-head period, discontinue flow, and monitor the head level drop in the borehole at appropriate intervals over at least a 30-minute falling-head period.

10) Compute the permeability for the constant head portion of the test using methods outlined in the following: United States Bureau of Reclamation Procedure 73000-89: Performing Field Permeability Testing By The Well Permeameter Method. And USBR Procedure 7305-89: Field Permeability Test (Shallow-Well Permeameter Method). Note: Utilize stabilized flow rates observed near the end of the constant-head period in the permeability calculations.

11) At a minimum the test report shall include a description of the equipment used to conduct the test (including type of flow meter used and the results of the on-site, flow meter accuracy check); difficulties encountered during drilling and testing, a subsurface log of the soils encountered; depth and diameter of the bore-hole; type of gravel-pack used (including visual description); type of slotted pipe used, raw data for both constant & falling head periods including

flow meter readings, incremental flow rates and observed head levels; and calculations showing how the reported permeability rates were computed.

Estimating Field Permeability of Soil-in-Place Using Test Pit Methods

(February 6, 1996)

Applicability

This test method is applicable for determining permeabilities for use in the design of non-standard, alternative subsurface disposal systems incorporating such features as subsurface trenches, subsurface galleries, low-profile drywells, etc. Note: Design deviation is required for all non-standard subsurface disposal systems.

Method

1) Excavate a rectangular test pit having approximate dimensions of 2 feet in width and 4 feet in length. Extend the pit until its bottom elevation is approximately 2 feet to 5 feet below the bottom elevation of the proposed drainage structure. As much as is practical, excavate the pit to neat-fine dimensions, and keep it free of surface slough, organics, and other deleterious material.

2) Line the walls and bottom of the pit with a highly porous, non-woven, geotextile fabric. Install a vertical, PVC observation pipe in the pit. Then backfill the pit with clean, uniform, pervious, fine gravel; or clean, uniform, pervious, open-graded coarse gravel. Note that omission of the PVC observation pipe and pervious gravel backfill is an allowable practice.

3) Introduce clean water into the test pit using an in-line, commercially available, flow meter. Prior to the test, field check the accuracy of the flow meter using a suitable container of known volume (i.e., 5 gallon bucket, 55 gallon barrel, etc).

4) Raise the water level in the pit until a level consistent with the operating head anticipated in the proposed drainage structure is achieved. Based upon the soil permeability, the subsurface soil profile, and the water supply system available, head levels lower than those anticipated in the drainage structure are permitted.

5) Adjust the flow rate as needed to maintain the constant head level in the pit. Minimum required test time is 2 hours.

6) Monitor and record the flow rate required to maintain the constant-head level at appropriate intervals. In no case shall the interval exceed 15 minutes in length.

7) Continue maintaining the constant head until a stabilized flow rate has been achieved. Consider the flow rate stable when the incremental flow rate

required to maintain the head does not vary by more than about 5% between increments. The intent of this section is to achieve a relatively steady-state flow condition between the minimum 2 hour test time and a maximum test time of 2+1/2 hours. At the discretion of the on-site engineer or engineering technician, the test may be extended beyond the 2+1/2 hour maximum. Yes, it is a 2 hour minimum for the pit method.

8) Upon completion of the constant-head period, discontinue flow, and monitor the head level drop in the borehole at appropriate intervals over at least a 30-minute falling-head period.

9) Compute the permeability for the constant head portion of the test using methods outlined in the following: United States Bureau of Reclamation Procedure 73000-89: Performing Field Permeability Testing By The Well Permeameter Method. And USBR Procedure 7305-89: Field Permeability Test (Shallow-Well Permeameter Method). Note: Utilize stabilized flow rates observed near the end of the constant-head period in the permeability calculations. See section 13.3 of USBR Procedure 7300-89 for test pit method.

10) At a minimum the test report shall include a description of the equipment used to conduct the test (including type of flow meter used and the results of the on-site, flow meter accuracy check); difficulties encountered during excavation and testing; a subsurface soil log of the test pit; test pit dimensions; color photographs or color reproductions showing the excavation and soil types encountered; type of fabric lining and/or gravel backfill used; raw data for both constant & failing head periods including flow meter readings, incremental flow rates and observed head levels; and calculations showing how the reported permeability rates were computed.

Estimating Surface Infiltration Rate and Field Permeability Rate Using Single-Ring Infiltrometer Methods

(February 6, 1996)

Applicability

Test method is applicable for estimating infiltration and permeability rates for surficial soils in conjunction with non-standard, subsurface disposal systems incorporating infiltration ponds. Note: Design deviation is required for all nonstandard subsurface disposal systems.

Method

1) Drive, jack, or hand-advance a short section of steel or PVC pipe having a minimum inside diameter of approximately 12 inches, and a beveled leading edge into the soil surface to a depth of about 8 inches. If after installation the surface of the soil surrounding the wall of the ring shows signs of excessive disturbance such as extensive cracking or heaving, reset the ring at another location using methods that will minimize the disturbance. If the surface of

the soil is only slightly disturbed, tamp the soil surrounding the inside and outside wall of the ring until it is as firm as it was prior to disturbance.

2) Introduce clean water into the ring using an in-line, commercially available, flow meter. Prior to the test, field check the accuracy of the flow meter using a suitable container of known volume (i.e. 5 gallon bucket, etc). Use some form of splash-guard or diffuser apparatus such as a highly porous, non-woven, geotextile fabric or a sheet of thin aluminum plate to prevent erosion of the surface of the soil during filling and testing.

3) Raise the water level in the ring until a head-level of at least 6 inches above the soil surface is achieved.

4) Adjust the flow rate as needed to maintain the constant head level in the ring. Minimum required test time is 2 hours.

5) Monitor and record the flow rate required to maintain the constant-head level at appropriate intervals. In no case shall the interval exceed 10 minutes in length.

6) Continue maintaining the constant head until a stabilized flow rate has been achieved. Consider the flow rate stable when the incremental flow rate required to maintain the head does not vary by more than about 5% between increments. The intent of this section is to achieve a relatively steady-state flow condition between the minimum 2 hour test time and a maximum test time of 2+1/2 hours. At the discretion of the on-site engineer or engineering technician, the test may be extended beyond the 2+1/2 hour maximum.

7) Upon completion of the constant-head period, discontinue flow, and monitor the head level drop in the ring at appropriate intervals over at least a 30-minute falling-head period.

8) Compute the surface infiltration rate using the equation: $I = Q/A$ Where I is the surface infiltration rate, Q is the flow rate required to maintain the constant head, and A is the surface area of the soil inside the infiltrometer ring. Use stabilized flow rates observed near the end of the constant-head period to compute the rate.

9) Compute the permeability rate using the following equation:

$$K = (Q * L) / (A * H)$$

Where Q is the flow rate required to maintain the constant head, L is the length of soil column contained within the ring, A is the area of the ring, and H is the head level measured from the base of the ring to the free water surface. This equation is based upon information presented in the U.S. Bureau of Reclamation Drainage Manual section 3-8: Ring Permeameter Test. Use stabilized flow rates observed near the end of the constant head period to compute the rate.

10) At a minimum the test report shall include a description of the equipment used to conduct the test (including type of flow meter used and the results of the

on-site, flow meter accuracy check); a subsurface log of the soils encountered (if test was conducted in the bottom of a test pit), difficulties encountered during testing; raw data for both constant and falling head periods including flow meter readings, incremental flow rates, and observed head levels; and calculations showing how the infiltration and permeability rates were computed.

Estimating Outflow Rate from a Drywell under Full-Scale, Constant Head Conditions

(February 6, 1996)

Applicability

This test method is applicable for confirmation of design outflow rates for newly installed standard and non-standard drywells.

Method

1) Inspect the drywell and make a thorough report of its condition. At a minimum include information on any silt build-up; if there is any standing water in the drywell; whether it is interconnected to other drywells or catch basins by pipes; the overall depth of the drywell from finished grate elevation to bottom; the distance from finished grate elevation to the invert elevation of any interconnecting pipes; the length of the active barrel section. The active barrel section is defined as the length of ported sections from the bottom of the drywell up to the elevation of the base of the solid cone section. Include additional information as is applicable (i.e. age of the drywell, if it appears to have been heavily impacted by unusual factors such as construction practices, etc).
2) Introduce clean water into the drywell using a calibrated, in-line commercially available flow meter.
3) Raise the water level in the drywell until it reaches the top of the active barrel section and then maintain it at that elevation. In the case of drywells interconnected by pipes, raise the water level to the invert elevation of the connecting pipe, or use an expandable pipe plug to seal the connecting pipe.
4) Adjust the flow rate as needed to maintain the constant head level in the hole. Minimum required test time is I hour. Test time begins after the water level in the drywell has reached the top of the active barrel section, or the invert elevation of any interconnecting pipes.
5) Monitor the flow rate required to maintain the constant head level in the drywell at appropriate intervals. In no case shall the interval exceed 10 minutes in length.
6) Continue maintaining the constant head level in the drywell until a stabilized flow rate has been achieved. Consider the flow rate stable when the incremental flow rate required to maintain the head does not vary by more

than 5% between increments. The intent of this section is to achieve a relatively steady-state flow condition between the minimum I hour test time and a maximum test time of 2 hours. At the discretion of the on-site engineer or engineering technician, the test may be extended beyond the 2 hour maximum.

7) Upon completion of the constant head period, discontinue flow and monitor the head level drop in the drywell at appropriate intervals for a 30 minute falling head period.

8) Report test data in a format which includes time of day, flow meter readings, incremental flow rates, observed head levels and water depths in the drywell, and total flow volumes.

References

U.S. Bureau of Reclamation (USBR) 7300-89: Performing Field Permeability Testing by the Well Permeameter Method

U.S. Bureau of Reclamation (USBR) 7305-89: Field Permeability Test (Shallow-Well Permeameter Method)

U.S. Bureau of Reclamation (USBR): Drainage Manual, Chapter 3 - Field & Laboratory Procedures

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Chapter 7 - Construction Stormwater Pollution Prevention

7.1 Introduction

7.1.1 Objective

This chapter provides guidance on planning, design, and implementation of stormwater management practices at construction sites. Runoff from development project sites during the construction phase can contribute to sedimentation of streams and carry other contaminants sufficient to result in water quality violations in receiving waters. Controlling erosion and preventing sediment and other pollutants from leaving the project site during the construction phase is achievable through implementation of selected Best Management Practices (BMPs) that are appropriate both to the site and to the season during which construction activities take place.

The objective of this chapter is to provide guidance for avoiding adverse stormwater impacts from construction activities on downstream resources and on-site stormwater facilities. Minimization of stormwater flows, prevention of soil erosion, capture of water-borne sediment that has been unavoidably released from exposed soils, and protection of water quality from on-site pollutant sources are all readily achievable when the proper BMPs are planned, installed, and properly maintained.

Initial discussions between the project proponents and their designer can identify approaches to accomplishing a high quality, cost-effective project without compromising environmental protection. Often new ways are found to stage, time, and phase parts of a project to economize a contractor's schedule and use of construction materials. This collaborative planning process can produce methods to minimize or eliminate vulnerability and unnecessary risk associated with some traditional construction practices and techniques.

The construction phase of a project is usually considered a temporary condition, which will be supplanted by the permanent improvements and facilities for the completed project. However, construction work may take place over an extended period of time, including several seasons of multiple years. All management practices and control facilities used in the course of construction should be of sufficient size, strength, and durability to readily outlast the longest possible construction schedule and the worst anticipated rainfall conditions.

Linear projects, such as roadway construction and utility installations, are special cases of construction activities and present their own, unique set of stormwater protection challenges. Many of the BMPs can be adapted and modified to provide the controls needed to adequately address these projects. It may by advantageous to segment long, linear projects into a series of separate units that can apply all necessary controls pertinent to that particular unit in a timely manner.

The goal of a Construction Stormwater Pollution Prevention Plan (SWPPP) is to avoid immediate and long-term environmental loss and degradation typically caused by poorly managed construction sites. Prompt implementation of a Construction SWPPP, designed in accordance with this chapter, can provide a number of benefits. These include minimizing construction delays, reducing resources spent on repairing erosion, improving the relationship between the contractor and the permitting authority, and limiting adverse effects on the environment.

Many of the BMPs contained in this chapter can be adapted and modified to provide the erosion and sediment controls needed for other activities such as mining.

7.1.2 Content and Organization of this Chapter

This chapter consists of four sections that address the key considerations and mechanics of preparing and implementing Construction SWPPPs.

- Section 7.1 highlights the importance of construction stormwater management in preventing pollution of surface waters. The section briefly lists the twelve elements of pollution prevention to be considered for all projects. The twelve elements are fully detailed in Section 7.2. Erosion and sedimentation processes and impacts are also described.
- Section 7.2 presents a step-by-step method for developing a Construction SWPPP. It encourages examination of all possible conditions that could reasonably affect a particular project's stormwater control systems during the construction phase of the project. Section 7.2.2 provides detailed descriptions of each of the twelve elements of Construction Stormwater Pollution Prevention. Section 7.2.3 provides a Construction SWPPP checklist.
- Section 7.3 contains BMPs for construction stormwater control and site management. Section 7.3.1 contains BMPs for Source Control. Section 7.3.2 addresses runoff, conveyance, and treatment BMPs. Various combinations of these BMPs should be used in the Construction SWPPP to satisfy each of the twelve elements of construction stormwater management that apply to the project.

7.1.3 How to Use This Chapter

This chapter should be used in developing the Construction Stormwater Pollution Prevention Plan (SWPPP), which is a required component of a Stormwater Site Plan (SSP, see also Chapter 3). Users should refer to this introductory section for an overview of construction stormwater issues, particularly related to erosion and sedimentation. Users should read

Section 7.2 to determine the organization and content of the Construction SWPPP. This chapter includes lists of suggested BMPs to meet each element of construction stormwater pollution prevention. Based on these lists, the project proponent should refer to Section 7.3 to determine which BMPs will be included in the Construction SWPPP, and to design and document application of these BMPs to the project construction site.

7.1.4 Twelve Elements of Construction Stormwater Pollution Prevention

The twelve elements listed below must be considered in the development of the Construction SWPPP unless site conditions render the element unnecessary. If an element is considered unnecessary, the Construction SWPPP must provide the justification. These elements cover the general water quality protection strategies of limiting site impacts, preventing erosion and sedimentation, and managing activities and sources. The twelve elements are:

1. Mark Clearing Limits
2. Establish Construction Access
3. Control Flow Rates
4. Install Sediment Controls
5. Stabilize Soils
6. Protect Slopes
7. Protect Drain Inlets
8. Stabilize Channels And Outlets
9. Control Pollutants
10. Control De-Watering
11. Maintain BMPs
12. Manage the Project

A complete description of each element and associated BMPs is given in Section 7.2.2, under Step 3 of developing a Construction SWPPP.

7.1.5 Erosion and Sedimentation Impacts

Soil erosion and the resulting sedimentation produced by land development impacts the environment, damaging aquatic and recreational resources as well as aesthetic qualities. Erosion and sedimentation ultimately affect everyone.

Common examples of the impacts of erosion and sedimentation are:

- Natural, nutrient rich topsoils are eroded away, making re-establishment of vegetation difficult. Consequently, soil amendments and fertilizers must be applied. A properly functioning soil system is a sustained stormwater management mechanism. Vegetation and soil are not effectively sustained unless both are maintained in good condition.

- Siltation fills culverts and storm drains, decreasing capacities and increasing flooding and maintenance frequency.
- Detention facilities fill rapidly with sediment, decreasing storage capacity and increasing flooding.
- Infiltration devices become clogged and fail.
- Streams and harbors must be dredged to remove obstructions caused by sedimentation in order to restore navigability.
- Sediment in lakes builds more rapidly. Resulting shallow areas become covered by aquatic plants, reducing usability. Increased nutrient loading from phosphorus attached to soil particles and transported to lakes and streams can cause a change in the water pH, algal blooms and oxygen depletion that lead to eutrophication and fish kills.
- Treatment of water for domestic uses becomes more difficult and costly.
- Aesthetically pleasing, clear, clean water is replaced with turbid water in streams and lakeshores.
- Eroded soil particles decrease the viability of macro-invertebrates and food-chain organisms, impair the feeding ability of aquatic animals, clog gill passages of fish, and reduce photosynthesis.
- Successful fish spawning is diminished by sediment-clogged gravel. Sedimentation following spawning can smother the eggs or young fry.

Costs associated with these impacts can be obvious or subtle. Some are difficult to quantify, such as the loss of aesthetic values or recreational opportunities. Restoration and management of a single lake can cost millions of dollars. Reductions in spawning habitat, and subsequent reduction in salmon and trout production, cause economic losses to sports fisheries and traditional Native American fisheries. The maintenance costs of man-made structures and harbors are readily quantifiable. Citizens pay repeatedly for these avoidable costs as city, county, state, and federal taxpayers.

Effective erosion and sediment control practices on construction sites can greatly reduce undesirable environmental impacts and costs. Being aware of the erosion and sedimentation process is helpful in understanding the role of BMPs in controlling stormwater runoff.

7.1.6 Erosion and Sedimentation Processes

Soil Erosion

Soil erosion is defined as the removal of soil from its original location by the action of water, ice, gravity, or wind. In construction activities, soil erosion is largely caused by the force of falling and flowing water. Erosion by water includes the following processes (see Figure 7.1.1):

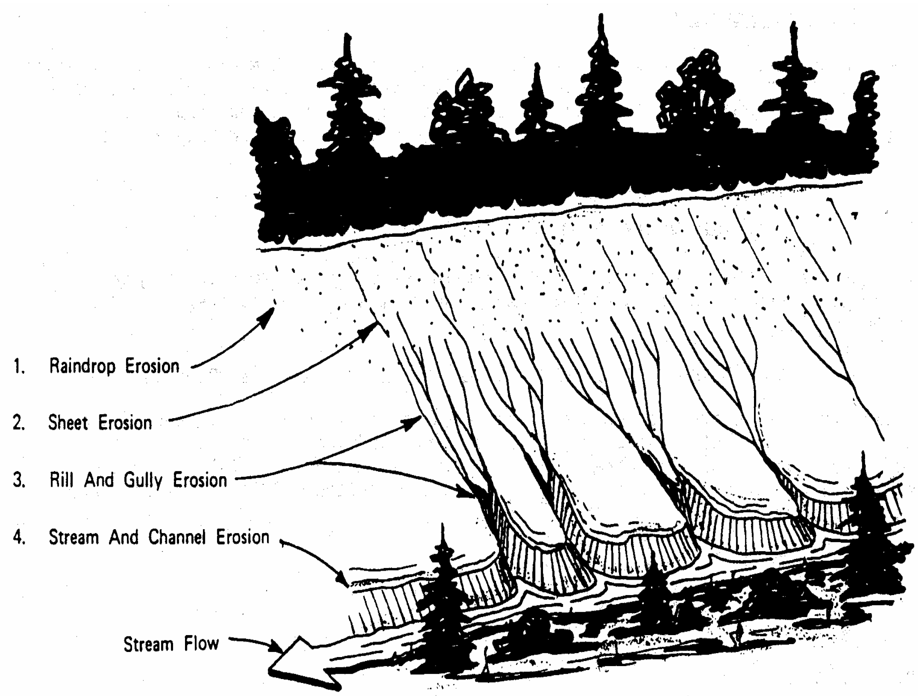

Figure 7.1.1 Types of erosion

- Raindrop Erosion: The direct impact of falling drops of rain on soil dislodges soil particles so that they can then be easily transported by runoff.
- Sheet Erosion: The removal of a layer of exposed soil by the action of raindrop splash and runoff, as water moves in broad sheets over the land and is not confined in small depressions.
- Rill and Gully Erosion: As runoff concentrates in rivulets, it cuts grooves called rills into the soil surface. If the flow of water is sufficient, rills may develop into larger gullies.
- Stream and Channel Erosion: Increased volume and velocity of runoff in an unprotected, confined channel may cause stream meander instability and scouring of significant portions of the stream or channel banks and bottom.
- Soil erosion by wind creates a water quality problem when dust is blown into water. Dust control on paved streets using washdown

waters, if not conducted properly, can also create water quality problems.

Sedimentation

Sedimentation is defined as the gravity-induced settling of soil particles transported by water. The process is accelerated in slower-moving, quiescent stretches of natural waterbodies or in treatment facilities such as sediment ponds and wetponds.

Sedimentation occurs when the velocity of water in which soil particles are suspended is slowed for a sufficient time to allow particles to settle. The settling rate is dependent on the soil particle size. Heavier particles, such as sand and gravel, can settle more rapidly than fine particles such as clay and silt. Sedimentation of clay soil particles is reduced due to clay's relatively low density and electro-charged surfaces, which discourage aggregation. The presence of suspended clay particles in stormwater runoff can result in highly turbid water, which is very difficult to clarify using standard sediment control BMPs. Turbidity, an indirect measure of soil particles in water, is one of the primary water quality standards in Washington State law (WAC 173-201A-030). Turbidity is increased when erosion carries soil particles into receiving waters. Treating stormwater to reduce turbidity can be an expensive, difficult process with limited effectiveness. Any actions or prevention measures that reduce the volume of water needing treatment for turbidity are beneficial.

7.1.7 Factors Influencing Erosion Potential

The erosion potential of soils can be readily determined using various models such as the Flaxman Method or the Revised Universal Soil Loss Equation (RUSLE).

The soil erosion potential of an area, including a construction site, is determined by four interrelated factors (see Figure 7.1.2):

- Soil characteristics
- Vegetative cover;
- Topography
- Climate

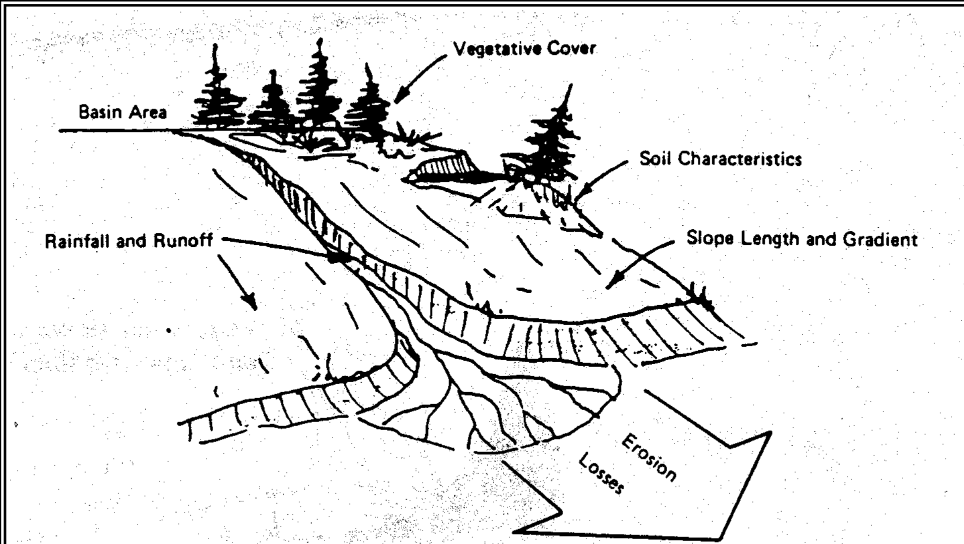

Figure 7.1.2   Factors Influencing Erosion Potential

Collection, analysis, and use of detailed information specific to the construction site for each of these four factors can provide the basis for an effective construction stormwater management system.

The first three factors, soil characteristics, vegetative cover, and topography are constant with respect to time until altered intentionally by construction. The designer, developer, and construction contractor should have a working knowledge about and control over these factors to provide high quality stormwater results.

The fourth factor, climate, is predictable by season, historical record, and probability of occurrence. While predicting a rainfall event is not possible, many of the impacts of construction stormwater runoff can be minimized or avoided by planning appropriate seasonal construction activity and using properly designed BMPs.

Soil Characteristics

The vulnerability of soil to erode is determined by soil characteristics: particle size, organic content, soil structure, and soil permeability.

Particle Size: Soils that contain high proportions of silt and very fine sand are generally the most erodible and are easily detached and carried away. The erodibility of soil decreases as the percentage of clay or organic matter increases; clay acts as a binder and tends to limit erodibility. Most soils with a high clay content are relatively resistant to detachment by rainfall and runoff. Once eroded, however, clays are easily suspended and settle out very slowly.

Organic Content: Organic matter creates a favorable soil structure, improving its stability and permeability. This increases infiltration capacity, delays the start of erosion, and reduces the amount of runoff.

The addition of organic matter increases infiltration rates (and, therefore, reduces surface flows and erodibility), water retention, pollution control, and pore space for oxygen.

Soil Structure: Organic matter, particle size, and gradation affect soil structure, which is the arrangement, orientation, and organization of particles. When the soil system is protected from compaction, the natural decomposition of plant debris on the surface maintains a healthy soil food web. The soil food web in turn maintains the porosity both on and below the surface.

Soil Permeability: Soil permeability refers to the ease with which water passes through a given soil. Well-drained and well-graded gravel and gravel mixtures with little or no silt are the least erodible soils. Their high permeability and infiltration capacity helps prevent or delay runoff.

Vegetative Cover

Vegetative cover plays an extremely important role in controlling erosion by:

- Shielding the soil surface from the impact of falling rain.
- Slowing the velocity of runoff, thereby permitting greater infiltration.
- Maintaining the soil's capacity to absorb water through root zone uptake and evapotranspiration.
- Holding soil particles in place.

Erosion can be significantly reduced by limiting the removal of existing vegetation and by decreasing duration of soil exposure to rainfall events. Give special consideration to the preservation of existing vegetative cover on areas with a high potential for erosion such as erodible soils, steep slopes, drainage ways, and the banks of streams. When it is necessary to remove vegetation, such as for noxious weed eradication, the area should be revegetated at the earliest possible window for successful seeding.

Topography

The size, shape, and slope of a construction site influence the amount and rate of stormwater runoff. Each site's unique dimensions and characteristics provide both opportunities for and limitations on the use of specific control measures to protect vulnerable areas from high runoff amounts and rates. Slope length, steepness, and surface texture are key elements in determining the volume and velocity of runoff. As slope length and/or steepness increase the rate of runoff and the potential for erosion increases. Slope orientation is also a factor in determining erosion potential. For example, a slope that faces south and contains droughty soils may provide such poor growing conditions that vegetative cover will be difficult to re-establish.

Climate

Seasonal temperatures and the frequency, intensity, and duration of rainfall are fundamental factors in determining amounts of runoff. As the volume and the velocity of runoff increase, the likelihood of erosion increases. Where storms are frequent, intense, or of long duration, erosion risks are high. Seasonal changes in temperature, as well as variations in rainfall, help to define the period of the year when there is a high erosion risk. When precipitation falls as snow, no erosion occurs. In the spring, melting snow adds to the runoff, and erosion potential will be higher. If the ground is still partially frozen, infiltration capacity is reduced. Eastern Washington is characterized in fall, winter, and spring by storms that are mild and long lasting. The fall and early winter events may saturate the soil profile and fill stormwater detention ponds, increasing the amount of runoff leaving the construction site. Shorter-term, more intense storms occur in the summer. These storms can cause problems if adequate BMPs have not been installed on-site.

7.2 Planning

This section provides an overview of the important components of, and the process for, developing and implementing a Construction Stormwater Pollution Prevention Plan (SWPPP).

- Section 7.2.1 contains general guidelines with which site planners should become familiar. It describes criteria for plan format and content and ideas for improved plan effectiveness.
- Section 7.2.2 outlines and describes a recommended step-by-step procedure for developing a Construction SWPPP from data collection to finished product. This procedure is written in general terms to be applicable to all types of projects.
- Section 7.2.3 includes a checklist for developing a Construction SWPPP.
- Design standards and specifications for Best Management Practices (BMPs) referred to in this section are found in Section 7.3 of this chapter.

The Construction SWPPP may be a subset of the Stormwater Site Plan (SSP) or construction plan set. Full details on how to integrate the Construction SWPPP with the SSP are provided in Chapter 3.

7.2.1 General SWPPP Guidelines

What is a Construction Stormwater Pollution Prevention Plan?

The Construction SWPPP is a document that describes the potential for pollution problems on a construction project. The Construction SWPPP includes a narrative, drawings and details that explains and illustrates the measures to be taken on the construction site to control those problems. The local jurisdiction may allow “small construction” projects to prepare a simpler Construction SWPPP, consisting of a checklist and a plot plan. “Small construction” is defined as construction activity that will disturb, or is part of a common plan of development that will cumulatively disturb, one to five acres of land.

The Construction SWPPP must be located on the construction site or within reasonable access to the site for construction and inspection personnel.

As site work progresses, the plan must be modified to reflect changing site conditions, subject to the rules for plan modification by the jurisdiction.

The owner or lessee of the land being developed has the responsibility for Construction SWPPP preparation and submission to local authorities. The owner or lessee may designate someone (i.e., an engineer, architect, contractor, etc.) to prepare the Construction SWPPP, but he/she retains the ultimate responsibility.

What is an Adequate SWPPP?

The Construction SWPPP must contain sufficient information to satisfy the Plan Approval Authority of the local government that the problems of pollution have been adequately addressed for the proposed project. An adequate Construction SWPPP includes a narrative and drawings. The narrative is a written statement to explain and justify the pollution prevention decisions made for a particular project. The narrative contains concise information about existing site conditions, construction schedules, and other pertinent items that are not contained on the drawings. The drawings and notes describe where and when the various BMPs should be installed, the performance the BMPs are expected to achieve, and actions to be taken if the performance goals are not achieved. If the construction schedule or other site specific information is not available or unknown during initial SWPPP preparation, the information can be added to the SWPPP at a later date.

On construction sites that discharge to surface water, the primary concern in the preparation of the Construction SWPPP is compliance with Washington State Water Quality Standards. Each of the 12 elements in Section 7.2.2 must be included in the Construction SWPPP unless an element is determined not to be applicable to the project and the exemption is justified in the narrative. The step-by-step procedure outlined in Section 7.2.2 is recommended for the development of the Construction SWPPPs. The checklists in Section 7.2.3 may be helpful in preparing and reviewing the Construction SWPPP.

On construction sites that infiltrate all stormwater runoff, the primary concern in the preparation of the Construction SWPPP is the protection of the infiltration facilities from fine sediments during the construction phase and protection of ground water from other pollutants. Several of the other elements are very important at these sites as well, such as marking the clearing limits, establishing the construction access, and managing the project.

As required by WAC 173-240, plans and specifications that involve "structures, equipment, or processes required to collect, carry away, treat, reclaim or dispose of industrial wastewater", including contaminated stormwater, must be prepared under the supervision of a licensed professional engineer (P.E.). However, aspects of the SWPPP that do not directly pertain to BMPs that collect, carry away, treat, reclaim or dispose of stormwater associated with construction activity (e.g. mulching, nets, blankets, seeding, etc.) do not need to be prepared under the supervision of a P.E..

BMP Standards and Specifications

Section 7.3 contains standards and specifications for the BMPs referenced throughout this chapter. Wherever any of these BMPs are to be employed on a site, the specific title and number of the BMP should be clearly referenced in the narrative and marked on the drawings.

The standards and specifications in Section 7.3 are not intended to limit any innovative or creative effort to effectively control erosion and sedimentation. In those instances where appropriate BMPs are not in this chapter, experimental management practices can be considered. Minor modifications to standard practices may also be employed. However, such practices must be approved by the plan approval authority of the local government before they may be used. All experimental management practices and modified standard practices are required to achieve the same or better performance than the BMPs listed in Section 7.3.

General Principles

The following general principles should be applied to the development of the Construction SWPPP.

- The duff layer, native topsoil, and natural vegetation should be retained in an undisturbed state to the maximum extent practicable.
- Prevent pollutant release. Select source control BMPs as a first line of defense. Prevent erosion rather than treat turbid runoff.
- Select BMPs depending on site characteristics (topography, drainage, soil type, ground cover, and critical areas) and the construction plan.
- Divert runoff away from exposed areas wherever possible. Keep clean water clean.
- Limit the extent of clearing operations and phase construction operations.

- Before seeding or planting permanent vegetation on an area where the topsoil has been stripped or compacted, the area should be reconditioned using the original topsoil and/or soil amendments such as compost to restore soil quality and promote successful revegetation.
- Incorporate natural drainage features whenever possible, using adequate buffers and protecting areas where flow enters the drainage system.
- Minimize slope length and steepness.
- Reduce runoff velocities to prevent channel erosion.
- Minimize the tracking of sediment off-site.
- Select appropriate BMPs for the control of pollutants other than sediment.
- Be realistic about the limitations of controls that you specify and the operation and maintenance of those controls. Anticipate what can go wrong, how you can prevent it from happening, and what will need to be done to fix it.

7.2.2 Step-By-Step Procedure

There are three basic steps in producing a Construction SWPPP:

- Step 1 - Data Collection
- Step 2 - Data Analysis
- Step 3 - Construction SWPPP Development and Implementation
- Steps 1 and 2 described below are intended for projects that are disturbing one acre or more. The jurisdiction permitting authority may allow single-family home construction projects to prepare a simpler Construction SWPPP, consisting of a checklist and a plot plan.

Step 1 - Data Collection

Evaluate existing site conditions and gather information that will help develop the most effective Construction SWPPP. The information gathered should be explained in the narrative and shown on the drawings.

Topography: Prepare a topographic drawing of the site to show the existing contour elevations at intervals of 1 to 5 feet depending upon the slope of the terrain.

Drainage: Locate and clearly mark existing drainage swales and patterns on the drawing, including existing storm drain pipe systems.

Soils: Identify and label soil type(s) and erodibility (low, medium, high or an index value from the NRCS manual) on the drawing. Soils information can be obtained from a soil survey if one has been published for the county. If a soil survey is not available, a request can be made to a district Natural Resource Conservation Service Office.

Soil permeability, percent organic matter, and effective depth should be expressed in average or nominal terms for the subject site or project. This information is frequently available in published literature, such as NRCS soil surveys. If it is not, the soils should be characterized by a qualified soil professional or engineer.

Ground Cover: Label existing vegetation on the drawing. Such features as tree clusters, grassy areas, and unique or sensitive vegetation should be shown. Unique vegetation may include existing trees above a given diameter. Local requirements regarding tree preservation should be investigated. In addition, existing denuded or exposed soil areas should be indicated.

Critical Areas: Delineate critical areas adjacent to or within the site on the drawing. Such features as steep slopes, streams, floodplains, lakes, wetlands, sole source aquifers, and geologic hazard areas, etc., should be shown. Delineate set backs and buffer limits for these features on the drawings. The local jurisdiction may have the critical areas largely established by local ordinance and the drawing should reflect those in addition to features identified by site inspection. Other related jurisdictional boundaries such as Shorelines Management and the Federal Emergency Management Agency (FEMA) base floodplain should also be shown on the drawings.

Adjacent Areas: Identify existing buildings, roads, and facilities adjacent to or within the project site on the drawings. Identify existing and proposed utility locations, construction clearing limits and erosion and sediment control BMPs on the drawings.

Existing Encumbrances: Identify wells, existing and abandoned septic drainfield, utilities, and site constraints.

Precipitation Records: Refer to Chapter 4 to determine the required rainfall records and the method of analysis for design of BMPs.

Step 2 - Data Analysis

Consider the data collected in Step 1 to visualize potential problems and limitations of the site. Determine those areas that have critical erosion hazards. The following are some important factors to consider in data analysis:

Topography: The primary topographic considerations are slope steepness and slope length. Because of the effect of runoff, the longer and steeper the slope, the greater the erosion potential. Erosion potential should be determined by a qualified engineer, soil professional, or certified erosion control specialist.

Drainage: Natural drainage patterns that consist of overland flow, swales and depressions should be used to convey runoff through the site to avoid constructing an artificial drainage system. Man-made ditches and waterways will become part of the erosion problem if they are not properly stabilized. Care should also be taken to ensure that increased runoff from the site will not erode or flood the existing natural drainage system. Possible sites for temporary stormwater retention and detention should be considered at this point.

Direct construction away from areas of saturated soil - areas where ground water may be encountered - and critical areas where drainage will concentrate. Preserve natural drainage patterns on the site.

Soils: Develop the Construction SWPPP based on known soil characteristics. Infiltration sites should be properly protected from clay and silt which will reduce infiltration capacities. Where necessary, evaluate soil properties such as surface and subsurface runoff characteristics, depth to impermeable layer, depth to seasonal ground water table, permeability, shrink-swell potential, texture, settleability, and erodibility.

Ground Cover: Ground cover is the most important factor in terms of preventing erosion. Existing vegetation that can be saved will prevent erosion better than constructed BMPs. Trees and other vegetation protect the soil structure. If the existing vegetation cannot be saved, consider such practices as phasing construction, temporary seeding, and mulching. Phasing of construction involves stabilizing one part of the site before disturbing another. In this way, the entire site is not disturbed at once.

Critical Areas: Critical areas may include flood hazard areas, mine hazard areas, slide hazard areas, sole source aquifers, wetlands, streambanks, fish-bearing streams, and other water bodies. Any critical areas within or adjacent to the development should exert a strong influence on land development decisions. Critical areas and their buffers shall be delineated on the drawings and clearly marked in the field. Only unavoidable work should take place within critical areas and their buffers. Such unavoidable work will require special BMPs, permit restrictions, and mitigation plans.

Adjacent Areas: An analysis of adjacent properties should focus on areas upslope and downslope from the construction project. Water bodies that will receive direct runoff from the site are a major concern. The types, values, and sensitivities of and risks to downstream resources, such as private property, stormwater facilities, public infrastructure, or aquatic systems, should be evaluated. Erosion and sediment controls should be selected accordingly.

Precipitation Records: Refer to Chapter 4 to determine the required rainfall records and the method of analysis for design of BMPs.

Timing of the Project: An important consideration in selecting BMPs is the timing and duration of the project. Projects that will proceed during the wet season and projects that will last through several seasons must take all necessary precautions to remain in compliance with the water quality standards.

Step 3 - Construction SWPPP Development and Implementation

After collecting and analyzing the data to determine the site limitations, the project proponent can then develop a Construction SWPPP. Each of the twelve elements below must be considered and included in the Construction SWPPP unless site conditions render the element unnecessary and the exemption from that element is clearly justified in the narrative of the SWPPP; the project proponent is granted flexibility in selecting appropriate BMPs to implement each element.

Element #1: Mark Clearing Limits

- Prior to beginning land disturbing activities, including clearing and grading, clearly mark all clearing limits, sensitive areas and their buffers, and trees that are to be preserved within the construction area. These shall be clearly marked, both in the field and on the plans, to prevent damage and offsite impacts.
- Plastic, metal, or stake wire fence may be used to mark the clearing limits.
- Suggested BMPs:

  BMP C101: Preserving Natural Vegetation
  BMP C102: Buffer Zones
  BMP C103: High Visibility Plastic or Metal Fence
  BMP C104: Stake and Wire Fence

Element #2: Establish Construction Access

- Construction vehicle access and exit shall be limited to one route if possible, while linear projects (e.g., roadways) should be limited to as few as possible.
- Access points shall be stabilized with quarry spalls or crushed rock to minimize the tracking of sediment onto public roads.
- Wheel wash or tire baths should be located on site, if applicable.
- If sediment is tracked off the construction site, roads shall be cleaned thoroughly at the end of each day. Sediment shall be removed from roads by shoveling or pickup sweeping and shall be transported to a controlled sediment disposal area. Street washing will be allowed only after sediment is removed in this manner.

- Street wash wastewater shall be controlled by pumping back on site or otherwise be prevented from discharging into systems tributary to state surface waters.
- Construction access restoration shall be equal to or better than the pre-construction condition.
- Suggested BMPs:

  BMP C105: Stabilized Construction Entrance
  BMP C106: Wheel Wash
  BMP C107: Construction Road/Parking Area Stabilization

Element #3: Control Flow Rates

- Properties and waterways downstream from development sites shall be protected from erosion due to increases in the volume, velocity, and peak flow rate of stormwater runoff from the project site, as required by local jurisdication.
- Downstream analysis is necessary if changes in offsite flows could impair or alter conveyance systems, streambanks, bed sediment, or aquatic habitat. Refer to Chapter 3 for additional details on how to perform a downstream analysis.
- The jurisdication may require pond designs that provide additional or different stormwater flow control. This may be necessary to address local conditions or to protect properties and waterways downstream from erosion due to increases in the volume, velocity, and peak flow rate of stormwater runoff from the project site.
- If permanent infiltration ponds are used for flow control during construction, these facilities should be protected from siltation during the construction phase.
- Suggested BMPs:

  BMP C240: Sediment Trap
  BMP C241: Temporary Sediment Pond
  Refer to Chapter 5, Detention, Retention and Infiltration Design

Element #4: Install Sediment Controls

- The duff layer, native top soil, and natural vegetation shall be retained in an undisturbed state to the maximum extent practicable.
- Prior to leaving a construction site or prior to discharge to an infiltration facility, stormwater runoff from disturbed areas shall pass through a sediment pond or other appropriate sediment removal BMP. Runoff from fully stabilized areas may be discharged without a sediment removal BMP, but must meet the flow control performance standard of Element #3, bullet #1. Full stabilization means concrete or asphalt paving; quarry spalls used as ditch lining; or the use of rolled

erosion products, a bonded fiber matrix product, or vegetative cover in a manner that will fully prevent soil erosion.

- BMPs intended to trap sediment on site shall be constructed as one of the first steps in grading. These BMPs shall be functional before other land disturbing activities take place.
- Earthen structures such as dams, dikes, and diversions shall be stabilized as per Element #5.
- BMPs intended to trap sediment on site shall be located in a manner to avoid interference with the movement of juvenile salmonids attempting to enter off-channel areas or drainages, often during non-storm events, in response to rain event changes in stream elevation or wetted area.
- Suggested BMPs:

  BMP C230: Straw Bale Barrier
  BMP C231: Brush Barrier
  BMP C232: Gravel Filter Berm
  BMP C233: Silt Fence
  BMP C234: Vegetated Strip
  BMP C235: Straw Wattles
  BMP C240: Sediment Trap
  BMP C241: Temporary Sediment Pond
  BMP C250: Construction Stormwater Chemical Treatment
  BMP C251: Construction Stormwater Filtration

Element #5: Stabilize Soils

- Exposed and unworked soils shall be temporarily or permanently stabilized as soon as practicable by application of effective BMPs that protect the soil from the erosive forces of raindrops, flowing water, and wind.
- No soils should remain exposed and unworked for more than the time periods set forth below to prevent wind and water erosion. This stabilization requirement applies to all soils on site, whether at final grade or not. This time limit may be adjusted by the jurisdiction if it can be shown that local precipitation data justifies a different standard.

  All of eastern Washington, except for the Central Basin (Region 2, see Figure 1.B or Figure 4.3.1):

  - During the regional dry season (July 1 through September 30): 10 days
  - During the regional wet season (October 1 through June 30): 5 days

  Central Basin (Region 2, see Figure 1.B or Figure 4.3.1):

    - During the regional dry season (July 1 through September 30): 30 days
    - During the regional wet season (October 1 through June 30): 15 days
- Soil stabilization BMPs shall be appropriate for the site conditions, time of year, and the duration of the project.
- The greatest potential for soil erosion, particularly in the driest parts of Eastern Washington, is during summer thunderstorms.
- Soil stockpiles shall be stabilized and protected with erosion and sediment control BMPs.
- Linear construction activities such as right-of-way and easement clearing, road construction, pipeline and utility installation, shall be conducted in accordance with this element.
- Suggested BMPs:

  BMP C120: Temporary and Permanent Seeding
  BMP C121: Mulching
  BMP C122: Nets and Blankets
  BMP C123: Plastic Covering
  BMP C124: Sodding
  BMP C125: Topsoiling
  BMP C126: Polyacrylamide for Soil Erosion Protection
  BMP C130: Surface Roughening
  BMP C131: Gradient Terraces
  BMP C140: Dust Control
  BMP C180: Small Project Construction Stormwater Pollution Prevention

Element #6: Protect Slopes

- Design, construct, and phase cut and fill slopes in a manner that will minimize erosion.
- Consider soil type and its potential for erosion.
- Reduce slope runoff velocities by reducing continuous length of slope with terracing and diversions, reduce slope steepness, and roughen slope surface.
- Divert upslope drainage and run-on waters with interceptors at top of slope. Stormwater from off site should be handled separately from stormwater generated on the site. Diversion of off-site stormwater around the site may be a viable option. Diverted flows shall be redirected to the natural drainage location at or before the property boundary.

- Contain downslope collected flows in pipes, slope drains, or protected channels. Check dams shall be used within channels that are cut down a slope.
- Provide drainage to remove ground water intersecting the slope surface of exposed soil areas.
- Excavated material shall be placed on the uphill side of trenches, consistent with safety and space considerations.
- Stabilize soils on slopes, as specified in Element #5.
- Suggested BMPs:

  BMP C120: Temporary and Permanent Seeding
  BMP C130: Surface Roughening
  BMP C131: Gradient Terraces
  BMP C200: Interceptor Dike and Swale
  BMP C201: Grass-Lined Channels
  BMP C204: Pipe Slope Drains
  BMP C205: Subsurface Drains
  BMP C206: Level Spreader
  BMP C207: Check Dams
  BMP C208: Triangular Silt Dike (Geotextile-Encased Check Dam)

Element #7: Protect Drain Inlets

- Storm drain inlets operable during construction shall be protected so that stormwater runoff does not enter the conveyance system without first being filtered or treated to remove sediment.
- Approach roads shall be kept clean. Sediment and street wash water shall not be allowed to enter storm drains without prior and adequate treatment unless treatment is provided before the storm drain discharges to waters of the state.
- Inlets should be inspected weekly at a minimum and daily during storm events. Inlet protection devices shall be cleaned or removed and replaced before sediment can accumulate to one-half the height for internal devices and one-third the height for external devices or as specified by the manufacturer.
- Suggested BMP:

  BMP C220: Storm Drain Inlet Protection

Element #8: Stabilize Channels and Outlets

- Temporary on-site conveyance channels shall be designed, constructed, and stabilized to prevent erosion from the expected peak flow velocity of the 6-month, 3-hour storm for the developed condition, referred to as the short duration storm.

- Stabilization, including armoring material, adequate to prevent erosion of outlets, adjacent streambanks, slopes, and downstream reaches shall be provided at the outlets of all conveyance systems.
- Suggested BMPs:

  BMP C202: Channel Lining
  BMP C209: Outlet Protection

Element #9: Control Pollutants

- All pollutants, including waste materials and demolition debris, that occur on site during construction shall be handled and disposed of in a manner that does not cause contamination of stormwater. Woody debris may be chopped and spread on site.
- Cover, containment, and protection from vandalism shall be provided for all chemicals, liquid products, petroleum products, and non-inert wastes present on the site (see Chapter 173-304 WAC for the definition of inert waste).
- Maintenance and repair of heavy equipment and vehicles involving oil changes, hydraulic system drain down, solvent and de-greasing cleaning operations, fuel tank drain down and removal, and other activities which may result in discharge or spillage of pollutants to the ground or into stormwater runoff must be conducted using spill prevention measures, such as drip pans. Contaminated surfaces shall be cleaned immediately following any discharge or spill incident. Emergency repairs may be performed on-site using temporary plastic placed beneath and, if raining, over the vehicle.
- Wheel wash or tire bath wastewater shall be discharged to a separate on-site treatment system or to the sanitary sewer.
- Application of agricultural chemicals including fertilizers and pesticides shall be conducted in a manner and at application rates that will not result in loss of chemical to stormwater runoff. Manufacturers' recommendations for application rates and procedures shall be followed.
- BMPs shall be used to prevent or treat contamination of stormwater runoff by pH modifying sources. These sources include bulk cement, cement kiln dust, fly ash, new concrete washing and curing waters, waste streams generated from concrete grinding and sawing, exposed aggregate processes, and concrete pumping and mixer washout waters. Stormwater discharges shall not cause a violation of the water quality standard for pH in the receiving water.
- Suggested BMPs: See also Chapter 8 – Source Control

  BMP C151: Concrete Handling
  BMP C152: Sawcutting and Surfacing Pollution Prevention

Element #10: Control De-Watering

- Foundation, vault, and trench de-watering water shall be discharged into a controlled conveyance system prior to discharge to a sediment pond. Channels shall be stabilized, as specified in Element #8.
- Clean, non-turbid de-watering water, such as well-point ground water, can be discharged to systems tributary to state surface waters, as specified in Element #8, provided the de-watering flow does not cause erosion or flooding of receiving waters. These clean waters should not be routed through stormwater sediment ponds.
- Highly turbid or contaminated dewatering water from construction equipment operation, clamshell digging, concrete tremie pour, or work inside a cofferdam shall be handled separately from stormwater.
- Other disposal options, depending on site constraints, may include:
  - Infiltration.
  - Transport off site in vehicle, such as a vacuum flush truck, for legal disposal in a manner that does not pollute state waters.
  - On-site treatment using chemical treatment or other suitable treatment technologies.
  - Sanitary sewer discharge with local sewer district approval, or use of a sedimentation bag with outfall to a ditch or swale for small volumes of localized dewatering.

Element #11: Maintain BMPs

- Temporary and permanent erosion and sediment control BMPs shall be maintained and repaired as needed to assure continued performance of their intended function. Maintenance and repair shall be conducted in accordance with BMP standards and specifications.
- Sediment control BMPs shall be inspected by project personnel every day when there is a discharge from the site (stormwater or non-stormwater), and at least weekly when there is no discharge. The inspection frequency for stabilized, inactive sites may be reduced to once every month.
- Temporary erosion and sediment control BMPs shall be removed within 30 days after final site stabilization is achieved or after the temporary BMPs are no longer needed. Trapped sediment shall be removed or stabilized on site. Disturbed soil resulting from removal of BMPs or vegetation shall be permanently stabilized.

Element #12: Manage the Project

- Phasing of Construction

  Development projects shall be phased where feasible in order to prevent, to the maximum extent practicable, the transport of sediment from the development site during construction. Revegetation of exposed areas and maintenance of that vegetation shall be an integral part of the clearing activities for any phase.

  Clearing and grading activities for developments will be permitted only if conducted pursuant to an approved site development plan (e.g., subdivision approval) that establishes permitted areas of clearing, grading, cutting, and filling. When establishing these permitted clearing and grading areas, consideration shall be given to minimizing removal of existing trees and minimizing disturbance and compaction of native soils except as needed for building purposes. These permitted clearing and grading areas and any other areas required to preserve critical or sensitive areas, buffers, native growth protection easements, or tree retention areas as may be required by local jurisdictions, shall be delineated on the site plans and the development site.

- Seasonal Work Limitations

  The jurisdication may impose a seasonal limitation on site disturbance. This decision may be based upon local weather conditions and/or other information provided including site conditions, the extent and nature of the construction activity, and the proposed erosion and sediment control measures.

  The jurisdiction may take enforcement action - such as a notice of violation, administrative order, penalty, or stop-work order under the following circumstances:

  - If, during the course of any construction activity or soil disturbance during the seasonal limitation period, sediment leaves the construction site causing a violation of the surface water quality standard; or
  - If clearing and grading limits or erosion and sediment control measures shown in the approved plan are not maintained.

  The following activities are exempt from the seasonal clearing and grading limitations:

  - Routine maintenance and necessary repair of erosion and sediment control BMPs;
  - Routine maintenance of public facilities or existing utility structures that do not expose the soil or result in the removal of the vegetative cover to soil; and

- Activities where there is one hundred percent infiltration of surface water runoff within the site in approved and installed erosion and sediment control facilities.

- Coordination with Utilities and Other Contractors

  The primary project proponent shall evaluate, with input from utilities and other contractors, the stormwater management requirements for the entire project, including the utilities, when preparing the Construction SWPPP.

- Inspection and Monitoring

  All BMPs shall be inspected, maintained, and repaired as needed to assure continued performance of their intended function.

  A Qualified Professional in Erosion and Sediment Control shall be identified in the Construction SWPPP and shall be on-site or on-call at all times. If this information is not available during SWPPP development, that should be noted in the narrative of the SWPPP. When the individual is identified, the information must be added to the SWPPP. See BMP C160 for qualifications.

  Sampling and analysis of the stormwater discharges from a construction site may be necessary on a case-by-case basis to ensure compliance with standards. The jurisdiction may establish monitoring and reporting requirements when necessary.

  Whenever inspection and/or monitoring reveals that the BMPs identified in the Construction SWPPP are inadequate, due to the actual discharge of or potential to discharge a significant amount of any pollutant, the SWPPP shall be modified, as appropriate, in a timely manner.

- Maintenance of the Construction SWPPP

  The Construction SWPPP shall be retained on-site or within reasonable access to the site. The Construction SWPPP shall be modified whenever there is a significant change in the design, construction, operation, or maintenance of any BMP.

7.2.3 Checklists for Construction SWPPPs

The Construction SWPPP consists of two parts: a narrative and the drawings. The two checklists in this section can be used to determine if all the major items are included in the Construction SWPPP.

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____

City/County Reference No. _______________________________________

Review Date: ____

On-site Inspection Review Date: ___________________________________

Construction SWPPP Reviewer: ____________________________________

Section I – Construction SWPPP Narrative

1. Construction Stormwater Pollution Prevention Elements

___ a. Describe how each of the Construction Stormwater Pollution Prevention Elements has been addressed though the Construction SWPPP.
___ b. Identify the type and location of BMPs used to satisfy the required element.
___ c. Justify and identify, if necessary, the reason an element is not applicable to the proposal.

> 12 Required Elements – Construction Stormwater Pollution Prevention Plan:

___ 1. Mark Clearing Limits
___ 2. Establish Construction Access
___ 3. Control Flow Rates
___ 4. Install Sediment Controls
___ 5. Stabilize Soils
___ 6. Protect Slopes
___ 7. Protect Drain Inlets
___ 8. Stabilize Channels and Outlets
___ 9. Control Pollutants
___10. Control De-Watering
___11. Maintain BMPs
___12. Manage the Project

2. Project Description

___ a. Total Project Area
___ b. Total proposed impervious area
___ c. Total proposed area to be disturbed
___ d. Total volumes of proposed cuts/fill

3. Existing Site Conditions

___ a. Description of the existing topography.
___ b. Description of the existing vegetation.
___ c. Description of the existing drainage

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____

City/County Reference No. ____

4. Adjacent Areas

___ I. Description of adjacent areas which may be affected by site disturbance

- ___ a. Streams
- ___ b. Lakes
- ___ c. Wetlands
- ___ d. Residential Areas
- ___ e. Roads
- ___ f. Other

___ II. Description of the downstream drainage path leading from the site to the receiving body of water. (Minimum distance of 400 yards.)

5. Critical Areas

- ___ a. Description of critical areas that are on or adjacent to the site.
- ___ b. Description of special requirements for working in or near critical areas.

6. Soils

___ Description of on-site soils.

- ___ a. Soil name(s)
- ___ b. Soil mapping unit
- ___ c. Erodibility
- ___ d. Settleability
- ___ e. Permeability
- ___ f. Depth
- ___ g. Texture
- ___ h. Soil Structure

7. Erosion Problem Areas

___ Description of potential erosion problems on site.

8. Construction Phasing

- ___ a. Construction sequence
- ___ b. Construction phasing (if proposed)

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____

City/County Reference No. ____

9. Construction Schedule

___ I. Provide a proposed construction schedule.

___ II. Wet Season Construction Activities

- ___ a. Proposed wet season construction activities.
- ___ b. Proposed wet season construction restraints for environmentally sensitive/critical areas.

10. Financial/Ownership Responsibilities

- ___ a. Identify the property owner responsible for the initiation of bonds and/or other financial securities.
- ___ b. Describe bonds and/or other evidence of financial responsibility for liability associated with erosion and sedimentation impacts.

11. Engineering Calculations

___ 1. Provide Design Calculations.

- ___ a. Sediment Ponds/Traps
- ___ b. Diversions
- ___ c. Waterways
- ___ d. Runoff/Stormwater Detention Calculations

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____

City Reference No. ____

Section II - Erosion and Sediment Control Plans

1. General

___ a. Vicinity Map
___ b. City/County of ____________ Clearing and Grading Approval Block
___ c. Erosion and Sediment Control Notes

2. Site Plan

___ a. Legal description of subject property.
___ b. North Arrow
___ c. Indicate boundaries of existing vegetation, e.g. tree lines, pasture areas, etc.
___ d. Identify and label areas of potential erosion problems.
___ e. Identify any on-site or adjacent critical areas and associated buffers.
___ f. Identify FEMA base flood boundaries and Shoreline Management boundaries (if applicable)
___ g. Show existing and proposed contours.
___ h. Indicate drainage basins and direction of flow for individual drainage areas.
___ i. Label final grade contours and identify developed condition drainage basins.
___ j. Delineate areas that are to be cleared and graded.
___ k. Show all cut and fill slopes indicating top and bottom of slope catch lines.

3. Conveyance Systems

___ a. Designate locations for swales, interceptor trenches, or ditches.
___ b. Show all temporary and permanent drainage pipes, ditches, or cut-off trenches required for erosion and sediment control.
___ c. Provide minimum slope and cover for all temporary pipes or call out pipe inverts.
___ d. Show grades, dimensions, and direction of flow in all ditches, swales, culverts and pipes.
___ e. Provide details for bypassing off-site runoff around disturbed areas.
___ f. Indicate locations and outlets of any dewatering systems.

4. Location of Detention BMPs

___ a. Identify location of detention BMPs.

Construction Stormwater Pollution Prevention Plan Checklist

Project Name: ____

City/County Reference No. ____

5. Erosion and Sediment Control Facilities

___ a. Show the locations of sediment trap(s), pond(s), pipes and structures.
___ b. Dimension pond berm widths and inside and outside pond slopes.
___ c. Indicate the trap/pond storage required and the depth, length, and width dimensions.
___ d. Provide typical section views through pond and outlet structure.
___ e. Provide typical details of gravel cone and standpipe, and/or other filtering devices.
___ f. Detail stabilization techniques for outlet/inlet.
___ g. Detail control/restrictor device location and details.
___ h. Specify mulch and/or recommended cover of berms and slopes.
___ i. Provide rock specifications and detail for rock check dam(s), if applicable.
___ j. Specify spacing for rock check dams as required.
___ k. Provide front and side sections of typical rock check dams.
___ l. Indicate the locations and provide details and specifications for silt fabric.
___ m. Locate the construction entrance and provide a detail.

6. Detailed Drawings

___ a. Any structural practices used that are not referenced in the Ecology Manual should be explained and illustrated with detailed drawings.

7. Other Pollutant BMPs

___ a. Indicate on the site plan the location of BMPs to be used for the control of pollutants other than sediment, e.g. concrete wash water.

8. Monitoring Locations

___ a. Indicate on the site plan the water quality sampling locations to be used for monitoring water quality on the construction site. Sampling stations shall be located upstream and downstream of the project site.

7.3 Standards and Specifications for Best Management Practices

Best Management Practices (BMPs) are defined as schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices, that when used singly or in combination, prevent or reduce the release of pollutants to waters of Washington State. This section contains standards and specifications for temporary BMPs to be used as applicable during the construction phase of a project.

- Section 7.3.1 contains the standards and specifications for Source Control BMPs.
- Section 7.3.2 contains the standards and specifications for Runoff Conveyance and Treatment BMPs.

The standards for each individual BMP are divided into four sections:

1. Purpose
2. Conditions of Use
3. Design and Installation Specifications
4. Maintenance Standards

Note that the "Conditions of Use" always refers to site conditions. As site conditions change, BMPs must be changed to remain in compliance.

Information on streambank stabilization is available in the *Integrated Streambank Protection Guidelines*, Washington State Department of Fish and Wildlife, 2000.

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7.3.1 Source Control BMPs

BMP C101: Preserving Natural Vegetation

Purpose

Purpose: The purpose of preserving natural vegetation is to reduce erosion wherever practicable. Limiting site disturbance is the single most effective method for reducing erosion. For example, conifers can hold up to about 50 percent of all rain that falls during a storm. Up to 20-30 percent of this rain may never reach the ground but is taken up by the tree or evaporates. Another benefit is that the rain held in the tree can be released slowly to the ground after the storm.

Conditions of Use:

- Natural vegetation should be preserved on steep slopes, near perennial and intermittent watercourses or swales, and on building sites in wooded areas.
- As required by jurisdiction.

Design and Installation Specifications: Natural vegetation can be preserved in natural clumps or as individual trees, shrubs and vines.

The preservation of individual plants is more difficult because heavy equipment is generally used to remove unwanted vegetation. The points to remember when attempting to save individual plants are:

- Is the plant worth saving? Consider the location, species, size, age, vigor, and the work involved. Local governments may also have ordinances to save natural vegetation and trees.
- Fence or clearly mark areas around trees that are to be saved. It is preferable to keep ground disturbance away from the trees at least as far out as the dripline.

Plants need protection from three kinds of injuries:

- Construction Equipment - This injury can be above or below the ground level. Damage results from scarring, cutting of roots, and compaction of the soil. Placing a fenced buffer zone around plants to be saved prior to construction can prevent construction equipment injuries.
- Grade Changes - Changing the natural ground level will alter grades, which affects the plant’s ability to obtain the necessary air, water, and minerals. Minor fills usually do not cause problems although sensitivity between species does vary and should be checked. Trees can tolerate fill of 6 inches or less. For shrubs and other plants, the fill should be less.

  When there are major changes in grade, it may become necessary to supply air to the roots of plants. This can be done by placing a layer of gravel and a tile system over the roots before the fill is made. A tile system protects a tree from a raised grade. The tile system should be laid out on the original grade leading from a dry well around the tree trunk. The system should then be covered with small stones to allow air to circulate over the root area.

  Lowering the natural ground level can seriously damage trees and shrubs.

The highest percentage of the plant roots are in the upper 12 inches of the soil and cuts of only 2-3 inches can cause serious injury. To protect the roots it may be necessary to terrace the immediate area around the plants to be saved. If roots are exposed, construction of retaining walls may be needed to keep the soil in place. Plants can also be preserved by leaving them on an undisturbed, gently sloping mound. To increase the chances for survival, it is best to limit grade changes and other soil disturbances to areas outside the dripline of the plant.

- Excavations - Protect trees and other plants when excavating for drainfields and power, water, and sewer lines. Where possible, the trenches should be routed around trees and large shrubs. When this is not possible, it is best to tunnel under them. This can be done with hand tools or with power augers. If it is not possible to route the trench around plants to be saved, then the following should be observed:
    - Cut as few roots as possible. When you have to cut, cut clean. Paint cut root ends with a wood dressing like asphalt base paint.
    - Backfill the trench as soon as possible.
    - Tunnel beneath root systems as close to the center of the main trunk to preserve most of the important feeder roots.

Some problems that can be encountered are:

- In general, most trees native to Eastern Washington do not readily adjust to major changes in environment and special care should be taken to protect these trees.
- The danger of windthrow increases where dense stands of coniferous trees have been thinned.
- Cottonwoods, maples, and willows have water-seeking roots. These can cause trouble in sewer lines and infiltration fields. On the other hand, they thrive in high moisture conditions that other trees would not.
- Thinning operations in pure or mixed stands of Grand fir, Pacific silver fir, Noble fir, Sitka spruce, Western red cedar, Western hemlock, Pacific dogwood, and Red alder can cause serious disease problems. Disease can become established through damaged limbs, trunks, roots, and freshly cut stumps. Diseased and weakened trees are also susceptible to insect attack.

Maintenance Standards:

- Inspect flagged and/or fenced areas regularly to make sure flagging or fencing has not been removed or damaged. If the flagging or fencing has been damaged or visibility reduced, it shall be repaired or replaced immediately and visibility restored.
- If tree roots have been exposed or injured, “prune” cleanly with an appropriate pruning saw or loppers directly above the damaged roots and recover with native soils.

BMP C102: Buffer Zones

Purpose: An undisturbed area or strip of natural vegetation or an established suitable planting that will provide a living filter to reduce soil erosion and runoff velocities.

Conditions of Use: Natural buffer zones are used along streams, wetlands and other bodies of water that need protection from erosion and sedimentation. Vegetative buffer zones can be used to protect natural swales and can be incorporated into the natural landscaping of an area.

Critical-areas buffer zones should not be used as sediment treatment areas. These areas shall remain completely undisturbed. The jurisdiction may expand the buffer widths temporarily to allow the use of the expanded area for removal of sediment.

Design and Installation Specifications

- Preserving natural vegetation or plantings in clumps, blocks, or strips is generally the easiest and most successful method.
- Leave all unstable steep slopes in natural vegetation.
- Mark clearing limits and keep all equipment and construction debris out of the natural areas. Steel construction fencing is the most effective method in protecting sensitive areas and buffers. Alternatively, wire-backed silt fence on steel posts is marginally effective. Flagging alone is typically not effective.
- Keep all excavations outside the dripline of trees and shrubs.
- Do not push debris or extra soil into the buffer zone area because it will cause damage from burying and smothering.
- Vegetative buffer zones for streams, lakes or other waterways shall be established by the jurisdiction or other state or federal permits or approvals.

Maintenance Standards:

- Inspect the area frequently to make sure flagging remains in place and the area remains undisturbed.

BMP C103: High Visibility Plastic or Metal Fence

Purpose: Fencing is intended to: (1) restrict clearing to approved limits; (2) prevent disturbance of sensitive areas, their buffers, and other areas required to be left undisturbed; (3) limit construction traffic to designated construction entrances or roads; and, (4) protect areas where marking with survey tape may not provide adequate protection.

Conditions of Use: To establish clearing limits, plastic or metal fence may be used:

- At the boundary of sensitive areas, their buffers, and other areas required to be left uncleared.
- As necessary to control vehicle access to and on the site.

Design and Installation Specifications:

- High visibility plastic fence shall be composed of a high-density polyethylene material and shall be at least four feet in height. Posts for the fencing shall be steel or wood and placed every 6 feet on center (maximum) or as needed to ensure rigidity. The fencing shall be fastened to the post every six inches with a polyethylene tie. On long continuous lengths of fencing, a tension wire or rope shall be used as a top stringer to prevent sagging between posts. The fence color shall be high visibility orange. The fence tensile strength shall be 360 lbs./ft. using the ASTM D4595 testing method.
- Metal fences shall be designed and installed according to the manufacturer's specifications.
- Metal fences shall be at least 3 feet high and must be highly visible.
- Fences shall not be wired or stapled to trees.

Maintenance Standards:

- If the fence has been damaged or visibility reduced, it shall be repaired or replaced immediately and visibility restored.

BMP C104: Stake and Wire Fence

Purpose: Fencing is intended to: (1) restrict clearing to approved limits; (2) prevent disturbance of sensitive areas, their buffers, and other areas required to be left undisturbed; (3) limit construction traffic to designated construction entrances or roads; and, (4) protect any areas where marking with survey tape may not provide adequate protection.

Conditions of Use: To establish clearing limits, stake or wire fence may be used:

- At the boundary of sensitive areas, their buffers, and other areas required to be left uncleared.
- As necessary, to control vehicle access to and on the site.

Design and Installation Specifications:

- See Figure 7.3.1 for details.
- More substantial fencing shall be used if the fence does not prevent encroachment into those areas that are not to be disturbed.

Maintenance Standards:

- If the fence has been damaged or visibility reduced, it shall be repaired or replaced immediately and visibility restored.

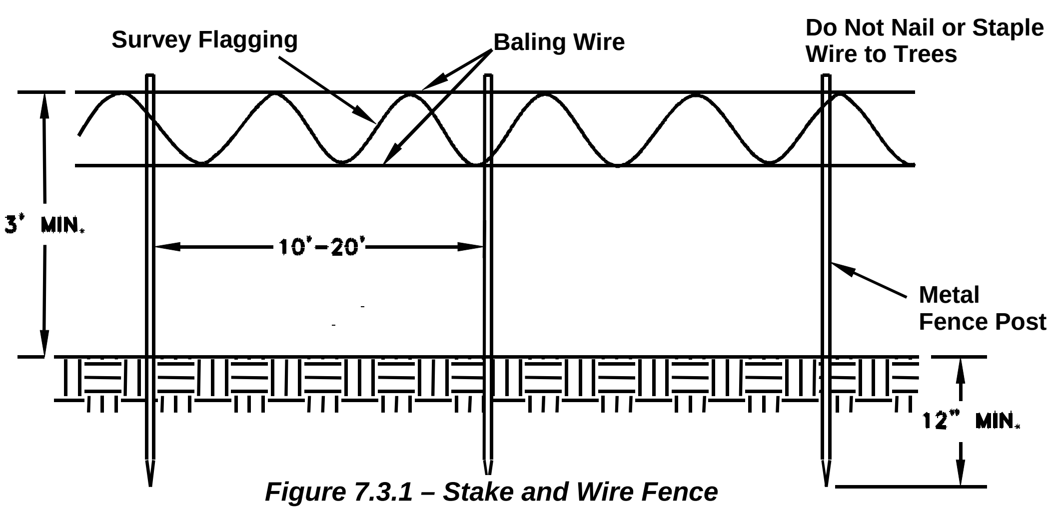


Figure 7.3.1 – Stake and Wire Fence

BMP C105: Stabilized Construction Entrance

Purpose: Construction entrances are stabilized to reduce the amount of sediment transported onto paved roads by vehicles or equipment by constructing a stabilized pad of quarry spalls at entrances to construction sites.

Conditions of Use:

- Construction entrances shall be stabilized wherever traffic will be leaving a construction site and traveling on paved roads or other paved areas within 1,000 feet of the site.
- On large commercial, highway, and road projects, the designer should include enough extra materials in the contract to allow for additional stabilized entrances not shown in the initial Construction SWPPP. It is difficult to determine exactly where access to these projects will take place; additional materials will enable the contractor to install them where needed.

Design and Installation:

- See Figure 7.3.2 for details.
- The surface material shall be 4”-8” quarry spalls. Smaller crushed rock such as base course may be appropriate in some situations but, since it is more likely to be tracked off-site, must be approved by the local jurisdiction.
- A separation geotextile shall be placed under the spalls to prevent fine sediment from pumping up into the rock pad. The geotextile shall meet the following standards:

Grab Tensile Strength (ASTM D4751)	200 psi min.
Grab Tensile Elongation (ASTM D4632)	30% max.
Mullen Burst Strength (ASTM D3786-80a)	400 psi min.
AOS (ASTM D4751)	20-45 (U.S. standard sieve size)

- If site conditions do not warrant the use of geotextile, it is not required.

Maintenance Standards: Quarry spalls (or hog fuel) shall be added if the pad is no longer in accordance with the specifications.

- If the entrance is not preventing sediment from being tracked onto pavement, then alternative measures to keep the streets free of sediment shall be used. This may include street sweeping, an increase in the dimensions of the entrance, or the installation of a wheel wash.
- Any sediment that is tracked onto pavement shall be removed by shoveling or street sweeping. The sediment collected by sweeping shall be removed or stabilized on site. The pavement shall not be cleaned by washing down the street, except when sweeping is ineffective and there is a threat to public safety. If it is necessary to wash the streets, the construction of a small sump shall be considered. The sediment would then be washed into the sump where it can be controlled.

- Any quarry spalls that are loosened from the pad, which end up on the roadway shall be removed immediately.
- If vehicles are entering or exiting the site at points other than the construction entrance(s), fencing (see BMPs C103 and C104) shall be installed to control traffic.
- Upon project completion and site stabilization, all construction accesses intended as permanent access for maintenance shall be permanently stabilized.

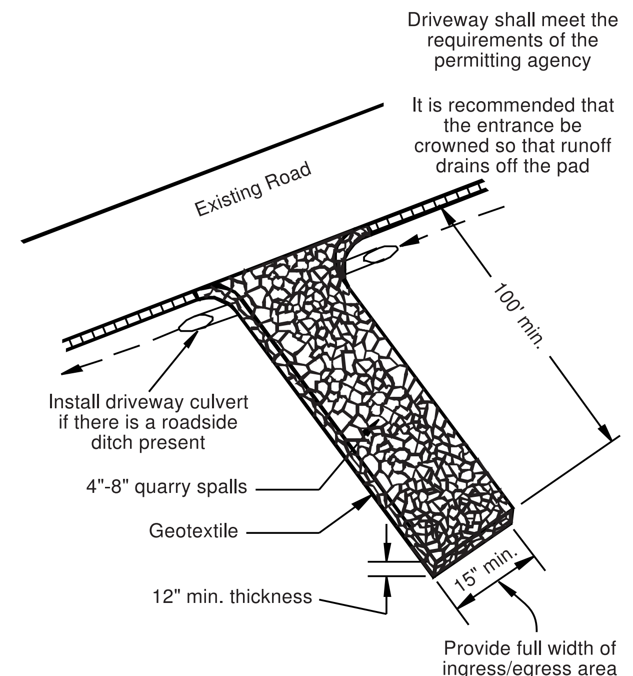


Figure 7.3.2 - Stabilized Construction Entrance

BMP C106: Wheel Wash

Purpose: Wheel washes reduce the amount of sediment transported onto paved roads by motor vehicles.

Conditions of Use:

- When a stabilized construction entrance (see BMP C105) is not preventing sediment from being tracked onto pavement.
- Wheel washing is generally an effective BMP when installed with careful attention to topography. For example, a wheel wash can be detrimental if installed at the top of a slope abutting a right-of-way where the water from the dripping truck can run unimpeded into the street.
- Pressure washing combined with an adequately sized and surfaced pad with direct drainage to a large 10-foot x 10-foot sump can be very effective.

Design and Installation Specifications: Suggested details are shown in Figure 7.3.3. The Jurisdiction may allow other designs. A minimum of 6 inches of asphalt treated base (ATB) over crushed base material or 8 inches over a good subgrade is recommended to pave the wheel wash.

Maintenance Standards:

- The wheel wash should start out the day with fresh water.
- The wash water should be changed a minimum of once per day. On large earthwork jobs where more than 10-20 trucks per hour are expected, the wash water will need to be changed more often.
- Wheel wash or tire bath wastewater shall be discharged to a separate on-site treatment system, such as closed-loop recirculation or land application, or to the sanitary sewer with proper local sewer district approval.

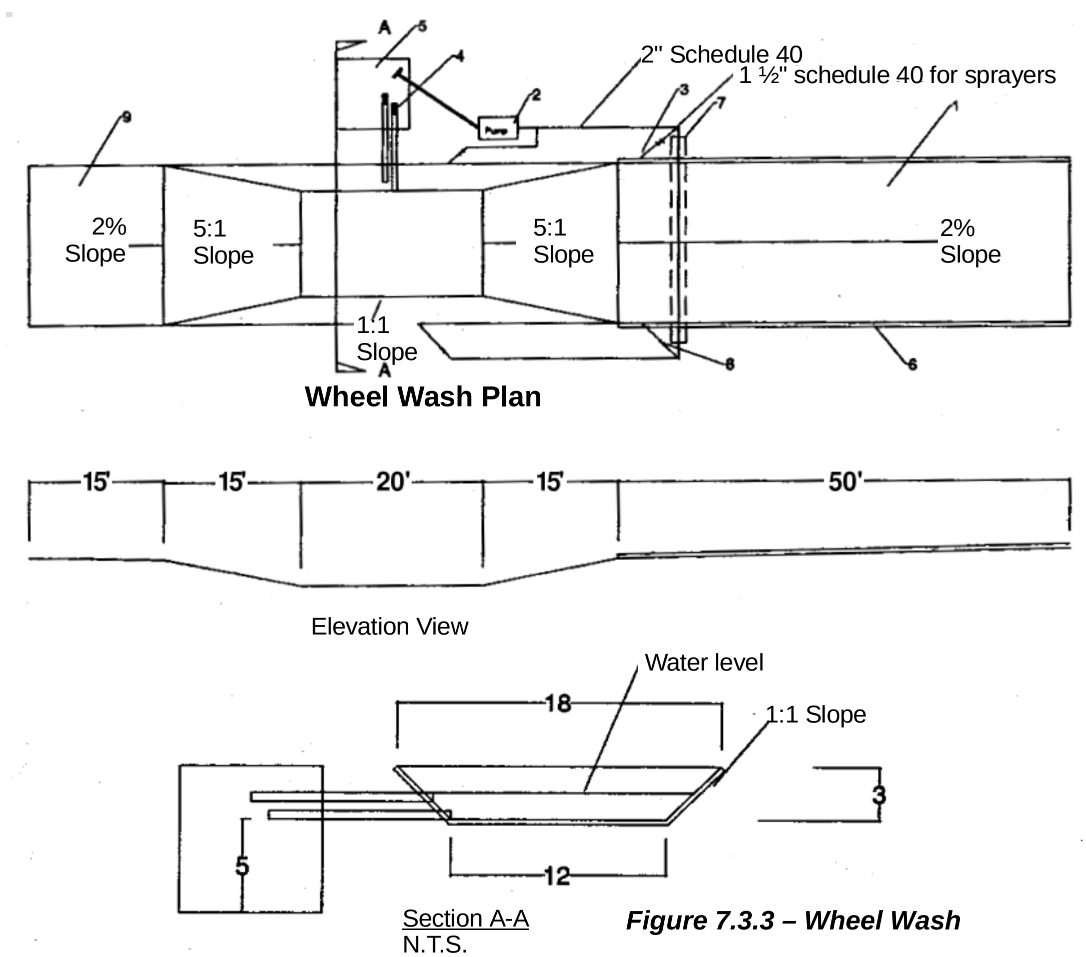


Figure 7.3.3 – Wheel Wash

Notes for Figure 7.3.3 – Wheel Wash:

1. Asphalt construction entrance 6 in. asphalt treated base (ATB).
2. 3-inch trash pump with floats on the suction hose.
3. Midpoint spray nozzles, if needed.
4. 6-inch sewer pipe with butterfly valves. Bottom one is a drain. Locate top pipe's invert 1 foot above bottom of wheel wash.
5. 8 foot x 8 foot sump with 5 feet of catch. Build so can be cleaned with trackhoe.
6. Asphalt curb on the low road side to direct water back to pond.
7. 6-inch sleeve under road.
8. Ball valves.
9. 15 foot. ATB apron to protect ground from splashing water.

BMP C107: Construction Road/Parking Area Stabilization

Purpose: Stabilizing subdivision roads, parking areas, and other onsite vehicle transportation routes immediately after grading reduces erosion caused by construction traffic or runoff.

Conditions of Use:

- Roads or parking areas shall be stabilized wherever they are constructed, whether permanent or temporary, for use by construction traffic.
- Fencing (see BMPs C103 and C104) shall be installed, if necessary, to limit the access of vehicles to only those roads and parking areas that are stabilized.

Design and Installation Specifications:

- On areas that will receive asphalt as part of the project, install the first lift as soon as possible.
- A 6-inch depth of 2- to 4-inch crushed rock, gravel base, or crushed surfacing base course shall be applied immediately after grading or utility installation. A 4-inch course of asphalt treated base (ATB) may also be used, or the road/parking area may be paved. It may also be possible to use cement or calcium chloride for soil stabilization. If cement or cement kiln dust is used for roadbase stabilization, pH monitoring and BMPs are necessary to evaluate and minimize the effects on stormwater. If the area will not be used for permanent roads, parking areas, or structures, a 6-inch depth of hog fuel may also be used, but this is likely to require more maintenance. Whenever possible, construction roads and parking areas shall be placed on a firm, compacted subgrade.
- Temporary road gradients shall not exceed 15 percent. Roadways shall be carefully graded to drain. Drainage ditches shall be provided on each side of the roadway in the case of a crowned section, or on one side in the case of a super-elevated section. Drainage ditches shall be directed to a sediment control BMP.
- Rather than relying on ditches, it may also be possible to grade the road so that runoff sheet-flows into a heavily vegetated area with a well-developed topsoil. Landscaped areas are not adequate. If this area has at least 50 feet of vegetation, then it is generally preferable to use the vegetation to treat runoff, rather than a sediment pond or trap. The 50 feet shall not include wetlands. If runoff is allowed to sheetflow through adjacent vegetated areas, it is vital to design the roadways and parking areas so that no concentrated runoff is created.
- Storm drain inlets shall be protected to prevent sediment-laden water entering the storm drain system (see BMP C220).

Maintenance Standards:

- Inspect stabilized areas regularly, especially after large storm events.
- Crushed rock, gravel base, hog fuel, etc. shall be added as required to maintain a stable driving surface and to stabilize any areas that have eroded.
- Following construction, these areas shall be restored to pre-construction condition or better to prevent future erosion.

BMP C120: Temporary and Permanent Seeding

Purpose: Seeding is intended to reduce erosion by stabilizing exposed soils. A well-established vegetative cover is one of the most effective methods of reducing erosion.

Conditions of Use:

- Seeding may be used throughout the project on disturbed areas that have reached final grade of that will remain unworked for more than 30 days.
- Channels that will be vegetated should be installed before major earthwork and hydroseeded with a Bonded Fiber Matrix. The vegetation should be well established (i.e., 75 percent cover) before water is allowed to flow in the ditch. With channels that will have high flows, erosion control blankets should be installed over the hydroseed. If vegetation cannot be established from seed before water is allowed in the ditch, sod should be installed in the bottom of the ditch over hydromulch and blankets.
- Retention/detention ponds should be seeded as required.
- Mulch is required at all times because it protects seeds from heat, moisture loss, and transport due to runoff.
- All disturbed areas should be reviewed prior to the beginning of the optimum seeding windows. Seeding shall be completed during the earliest optimal seeding window following disturbance. Otherwise, vegetation will not become established well enough to provide more than average soil protection.
- At final site stabilization, all disturbed areas not otherwise vegetated or stabilized shall be seeded and mulched. Final stabilization means the completion of all soil disturbing activities at the site and the establishment of a permanent vegetative cover, or equivalent permanent stabilization measures (such as pavement, riprap, gabions or geotextiles) which will prevent erosion.

Design and Installation Specifications:

- Seeding should be done during those seasons most conducive to growth and will vary with the climate conditions of the region. Local experience should be used to determine the appropriate seeding periods.
- The optimum permanent seeding window for Eastern Washington is October 1 through November 15; and the acceptable permanent seeding window is September 1 through April 30th. Seeding permanent species is not recommended from May 1 through August 31, unless irrigation is conducted.
- To prevent seed from being washed away, confirm that all required surface water control measures have been installed.
- The seedbed should be firm and rough. All soil should be roughened no matter what the slope. If compaction is required for engineering purposes,

slopes must be track walked before seeding. Backblading or smoothing of slopes greater than 4:1 is not allowed if they are to be seeded.

- New and more effective restoration-based landscape practices rely on deeper incorporation than that provided by a simple single-pass rototilling treatment. Wherever practical the subgrade should be initially ripped to improve long-term permeability, infiltration, and water inflow qualities. At a minimum, permanent areas shall use soil amendments to achieve organic matter and permeability performance defined in engineered soil/landscape systems. For systems that are deeper than 8 inches, the rototilling process should be done in multiple lifts, or the prepared soil system shall be prepared properly and then placed to achieve the specified depth.

- Because it is hard to generalize soil and climate conditions in eastern Washington, the project proponent is directed to check with the local Conservation District for appropriate seed and fertilizer types and application rates for their site.

- Organic matter is the most appropriate form of “fertilizer” because it provides nutrients (including nitrogen, phosphorus, and potassium) in the least water-soluble form. A natural system typically releases 20 to 10 percent of its nutrients annually. Chemical fertilizers have since been formulated to simulate what organic matter does naturally.

- It is recommended that areas being seeded for final landscaping conduct soil tests to determine the exact type and quantity of fertilizer needed. This will prevent the over-application of fertilizer. Fertilizer should not be added to the hydromulch machine and agitated more than 20 minutes before it is to be used. If agitated too much, the slow release coating is destroyed.

- There are numerous products available on the market which take the place of chemical fertilizers. A good, long-acting, slow release organic fertilizer is Biosol mix 7-2-3. It can be applied dry or with a hydroseeder. It should not be applied over snow. .

- Hydroseed applications shall include a minimum of 1,500 lbs. per acre of mulch with 3 percent tackifier. Mulch may be made up of 100 percent fibers made of wood, recycled cellulose, compost or blends of these. Tackifier shall be plant-based (such as guar or alpha plantago) or chemical-based (such as polyacrylamide or polymers). Any mulch or tackifier product used shall be installed per manufacturer’s instructions. Generally, mulches come in 40 to 50 lb. bags. Seed and fertilizer are added at time of application.

- Mulch is always required for seeding. Mulch can be applied on top of the seed or simultaneously by hydroseeding.

- On steep slopes, Bonded Fiber Matrix (BFM) or Mechanically Bonded Fiber Matrix (MBFM) products should be used. BFM/MBFM products are applied at a minimum rate of 3,000 lbs. per acre of mulch with approximately 10 percent tackifier. Application is made so that a minimum of 95 percent soil coverage is achieved. Numerous products are available commercially and should be installed per manufacturer's instructions. Most products required 24 to 36 hours to cure before a rainfall and cannot be installed on wet or saturated soils. Generally, these products come in 40 to 50 lb. bags and include all necessary ingredients except for seed and fertilizer.

BFMs and MBFMs have some advantages over blankets:

- No surface preparation required;
- Can be installed via helicopter in remote areas;
- On slopes steeper than 2:5:1, blanket installers may need to be roped and harnessed for safety;
- They are at least $1,000 per acre cheaper installed.

- When installing seed via hydroseeding operations, only about 1/3 of the seed actually ends up in contact with the soil surface. This reduces the ability to establish a good stand of grass quickly. One way to overcome this is to increase seed quantities by up to 50 percent.
- Vegetation establishment can also be enhanced by dividing the hydromulch operation into two phases:
  - Phase 1 – Install all seed and fertilizer with 25 to 30 percent mulch and tackifier onto the soil in the first lift;
  - Phase 2 – Install the remaining mulch and tackifier over the first lift.

An alternative is to install the mulch, seed, fertilizer, and tackifier in one lift. Then, spread or blow straw over the top of the hydromulch at a rate of about 800 to 1000 lbs. per acre. Hold straw in place with a standard tackifier. Both of these approaches will increase cost moderately but will greatly improve and enhance vegetative establishment. The increased cost may be offset by the reduced need for:

- Irrigation
- Reapplication of mulch
- Repair of failed slope surfaces

This technique works with standard hydromulch (1,500 lbs. per acre minimum) and BFM/MBFMs (3,000 lbs. per acre minimum).

In most cases, the shear strength of blankets is not a factor when used on slopes, only when used in channels. BFMs and MBFMs are good alternatives to blankets in most situations where vegetation establishment is the goal.

- Areas to be permanently landscaped shall provide a healthy topsoil or amend the existing soil to reduce the need for fertilizers, improve overall topsoil quality, provide for better plant health and vitality, improve hydrologic characteristics, and reduce the need for irrigation.

- Areas that already have good topsoil, such as undisturbed areas, do not require soil amendments.
- Areas that will be seeded only and not landscaped may need compost or meal-based mulch included in the hydroseed in order to establish vegetation. Native topsoil should be re-installed on the disturbed soil surface before application.
- Seed that is installed as a temporary measure may be installed by hand if it will be covered by straw, mulch, or topsoil. Seed that is installed as a permanent measure may be installed by hand on small areas (usually less than one acre) that will be covered with mulch, topsoil, or erosion blankets. The seed mixes listed below include recommended mixes for both temporary and permanent seeding. Alternative seed mixes approved by the local authority may be used.

  Local suppliers or the local conservation district should be consulted for their recommendations because the appropriate mix and application rate depend on a variety of factors, including location, exposure, soil type, slope, and expected foot traffic.

Table 7.3.1 shows seeding rates for the temporary stabilization of disturbed areas until permanent vegetation or other long-term erosion control measures can be established. These annual plants will generally not survive more than one growing season.

Table 7.3.1
Temporary Seeding

Common Name	**Seeding rate (lbs/ac)**			
	A	**B**	**C**	**D**
winter or spring wheat (I)	80			
spring barley (I)		80		
Regreen(I)* or triticale (I)			50	
annual ryegrass (I)				15
*sterile wheat x wheatgrass hybrid (N) = native plant species (I) = introduced, non-native plant species				

Table 7.3.2 shows three different erosion control seed mixes (Columns A, B and C) for upland areas that receive less than 12" effective precipitation. For each, drilled seeding rates are given (lbs/ac); double seed rates if broadcast or hydroseeded. Consideration should be given to the traffic hazard to wildlife when selecting food species for roadside stabilization.

Table 7.3.2
Permanent Seed Mixes: upland areas with less than 12" precipitation

Common Name	**Mixtures (lbs/ac)***		
	A	**B**	**C**
crested or siberian wheatgrass* (droughty, coarse soils)(I)	7		
bluebunch wheatgrass (N)		7	
indian ricegrass (sandy soil)(N)	2		
thickspike wheatgrass (N)			8
sheep fescue (I)		1	1
big bluegrass (N) <u>or</u> needle and thread grass (N)	1	1	
TOTAL	**10**	**9**	**9**
<u>Seeds/sq ft/mixture</u>	**<u>63</u>**	**<u>56</u>**	**<u>64</u>**
*Expressed as pure live seed (PLS). (N) = native plant species (I) = introduced, non-native plant species			

Table 7.3.3 shows three different erosion control seed mixes (Columns A, B and C) for upland areas that receive 12-15" effective precipitation. For each, drilled seeding rates are given (lbs/ac); double seed rates if broadcast or hydroseeded. Consideration should be given to the traffic hazard to wildlife when selecting food species for roadside stabilization.

Table 7.3.3
Permanent Seed Mixes: upland areas that receive 12–15" precipitation

Common Name	**Mixtures (lbs/ac)***		
	A	**B**	**C**
bluebunch <u>or</u> beardless wheatgrass (N)		8	
pubescent wheatgrass (I)			7
indian ricegrass (sandy or sandy loam soils)(N)	2		
thickspike wheatgrass (N)	7		2
sheep fescue (I)		1	2
basin wildrye (N)		1	
TOTAL	**9**	**10**	**11**
<u>Seeds/sq ft/mixture</u>	**<u>53</u>**	**<u>63</u>**	**<u>49</u>**
*Expressed as Pure Live Seed (PLS) (N) = native plant species (I) = introduced, non-native plant species			

Table 7.3.4 shows two different erosion control seed mixes (Columns A and B) for upland areas that receive 15-18” effective precipitation. For each, drilled seeding rates are given (lbs/ac); double seed rates if broadcast or hydroseeded. Consideration should be given to the traffic hazard to wildlife when selecting food species for roadside stabilization.

Table 7.3.4
Permanent Seed Mixes: upland areas with 15–18” precipitation

Common Name	**Mixtures (lbs/ac)***	
	A	**B**
bluebunch wheatgrass (N) <u>or</u> beardless wheatgrass (N)	8	
pubescent wheatgrass (I) <u>or</u> intermediate wheatgrass (I) <u>or</u> thickspike wheatgrass (N)		8
hard fescue (I) <u>or</u> sheep fescue (I)	2	2
big bluegrass (N)	1	1
Native legume (N)	2	2
TOTAL	**9**	**10**
<u>Seeds/sq ft/mixture</u>	**<u>70</u>**	**<u>72</u>**
*Expressed as Pure Live Seed (PLS) (N) = native plant species (I) = introduced, non-native plant species		

Table 7.3.5 shows three different erosion control seed mixes (Columns A, B and C) for upland areas that receive 18-24" effective precipitation. For each, drilled seeding rates are given (lbs/ac); double seed rates if broadcast or hydroseeded. Consideration should be given to the traffic hazard to wildlife when selecting food species for roadside stabilization.

Table 7.3.5
Permanent Seed Mixes: upland areas with 18–24" precipitation

Common Name	**Mixtures (lbs/ac)***		
	A	**B**	**C**
slender wheatgrass (N) <u>or</u> sodar streambank wheatgrass	7		
blue wildrye (N)		8	
mountain brome (N)	1		8
hard fescue (I)	2	2	2
white clover (I) <u>or</u> red clover (I)			2
native lupine (N) <u>or</u> northern sweetvetch (N)		2	
native clover spp. (N) <u>or</u> milkvetch spp. (N)	2		
TOTAL	**12**	**12**	**12**
<u>Seeds/sq ft/mixture</u>	**<u>64</u>**	**<u>62</u>**	**<u>76</u>**
*Expressed as Pure Live Seed (PLS) (N) = native plant species (I) = introduced, non-native plant species			

Table 7.3.6 shows two different erosion control seed mixes (Columns A and B) for upland areas that receive greater than 24” effective precipitation. For each, drilled seeding rates are given (lbs/ac); double seed rates if broadcast or hydroseeded. Consideration should be given to the traffic hazard to wildlife when selecting food species for roadside stabilization.

Table 7.3.6
Permanent Seed Mixes: upland areas with over 24” precipitation

Common Name	**Mixtures (lbs/ac)***	
	A	**B**
hard fescue (I)		2
blue wildrye (N)	6	
red fescue (I)	1	
mountain brome (N)	2	4
slender wheatgrass (N)		4
white clover (I)	2	
native legume (N)		2
TOTAL	**11**	**12**
Seeds/sq ft/mixture	**72**	**61**
*Expressed as Pure Live Seed (PLS) (N) = native plant species (I) = introduced, non-native plant species		

Table 7.3.7 shows seeding rates for the temporary stabilization of disturbed areas until permanent vegetation or other long-term erosion control measures can be established. These annual plants will generally not survive more than one growing season.

Table 7.3.7
Temporary Seeding

Common Name	**Seeding rate (lbs/ac)**			
	A	**B**	**C**	**D**
winter or spring wheat (I)	80			
spring barley (I)		80		
Regreen(I)* or triticale (I)			50	
annual ryegrass (I)				15
*sterile wheat x wheatgrass hybrid (N) = native plant species (I) = introduced, non-native plant species				

Table 7.3.8 shows three different erosion control seed mixes (Columns A, B and C) for stabilizing grassed waterways in areas that receive less than 15” effective precipitation. For each, drilled seeding rates are given (lbs/ac); double seed rates if broadcast or hydroseeded. Consideration should be given to the traffic hazard to wildlife when selecting food species for roadside stabilization.

Table 7.3.8
Permanent Seed Mixes: grassed waterways with less than 15” precipitation

Common Name	**Mixtures (lbs/ac)***		
	A	**B**	**C**
pubescent wheatgrass (I)		10	
streambank wheatgrass (N)			7
thickspike wheatgrass (N)	7		
sheep fescue (I)		2	2
big bluegrass (N	2		
TOTAL	**9**	**12**	**9**
Seeds/sq ft/mixture	**66**	**48**	**56**
*Expressed as pure live seed (PLS). (N) = native plant species (I) = introduced, non-native plant species			

Table 7.3.9 shows three different erosion control seed mixes (Columns A, B and C) for stabilizing grassed waterways in areas that receive 15-18" effective precipitation. For each, drilled seeding rates are given (lbs/ac); double seed rates if broadcast or hydroseeded. Consideration should be given to the traffic hazard to wildlife when selecting food species for roadside stabilization.

Table 7.3.9
Permanent Seed Mixes: grassed waterways with 15–18" precipitation

Common Name	**Mixtures (lbs/ac)***		
	A	**B**	**C**
tall wheatgrass (I)	10		
pubescent wheatgrass (I) <u>or</u> streambank wheatgrass (N) <u>or</u> intermedimate wheatgrass (I)		10	
hard fescue (I) <u>or</u> sheep fescue (I)	2	2	2
Thickspike wheatgrass (N)			8
TOTAL	**12**	**12**	**10**
<u>Seeds/sq ft/mixture</u>	**<u>46</u>**	**<u>48</u>**	**<u>57</u>**
*Expressed as Pure Live Seed (PLS) (N) = native plant species (I) = introduced, non-native plant species			

Table 7.3.10 shows three different erosion control seed mixes (Columns A, B and C) for stabilizing grassed waterways in areas that receive over 18" effective precipitation. For each, drilled seeding rates are given (lbs/ac); double seed rates if broadcast or hydroseeded. Consideration should be given to the traffic hazard to wildlife when selecting food species for roadside stabilization.

Table 7.3.10
Permanent Seed Mixes: grassed waterways with over 18" precipitation

Common Name	**Mixtures (lbs/ac)***		
	A	**B**	**C**
intermediate wheatgrass (I)	10		
mountain brome (N) or meadow brome		10	
anuual ryegrass (I) or perennial ryegrass (I)	4		
hard fescue (I)		2	
tall wheatgrass (I)			10
TOTAL	**14**	**12**	**10**
Seeds/sq ft/mixture	**40**	**46**	**38**
*Expressed as Pure Live Seed (PLS) (N) = native plant species (I) = introduced, non-native plant species			

Table 7.3.11 shows two different erosion control seed mixes (Columns A and B) for stabilizing ski-slopes or subalpine areas in Eastern Washington. For each, drilled seeding rates are given (lbs/ac); double seed rates if broadcast or hydroseeded. Consideration should be given to the traffic hazard to wildlife when selecting food species for roadside stabilization.

Table 7.3.11
Permanent Seed Mixes: stabilization of ski-slope and subalpine areas

Common Name	**Mixtures (lbs/ac)***	
	A	**B**
Blue wildrye (N) or Idaho fescue (N)	10	
Pubescent wheatgrass (I) or red fescue (I)		8
Hard fescue (I)		5
Sheep fescue (I)	2	2
white clover (I) or bentgrasses (I)		2
lupine (N)	2	
TOTAL	**14**	**17**
*Expressed as Pure Live Seed (PLS) (N) = native plant species (I) = introduced, non-native plant species		

Maintenance Standards:

- Any seeded areas that fail to establish at lest 80 percent cover (100 percent cover for areas that receive sheet or concentrated flows) shall be reseeded. If reseeding is ineffective, an alternate method, such as sodding, mulching, or nets/blankets, shall be used. If winter weather prevents adequate grass growth, this time limit may be relaxed at the discretion of the local authority when sensitive areas would otherwise be protected.
- After adequate cover is achieved, any areas that experience erosion shall be reseeded and protected by mulch. If the erosion problem is drainage related, the problem shall be fixed and the eroded area reseeded and protected by mulch.
- Seeded areas shall be supplied with adequate moisture, but not watered to the extent that causes runoff.

BMP C121: Mulching

Purpose: The purpose of mulching soils is to provide immediate temporary protection from erosion. Mulch also enhances plant establishment by conserving moisture, holding fertilizer, seed, and topsoil in place, and moderating soil temperatures. There is an enormous variety of mulches that can be used. Only the most common types are discussed in this section.

Conditions of Use: As a temporary cover measure, mulch should be used:

- On disturbed areas that require cover measures for less than 30 days.
- As a cover for seed during the wet season and during the hot summer months.
- During the wet season on slopes steeper than 3H:1V with more than 10 feet of vertical relief.
- Mulch may be applied at any time of the year and must be refreshed periodically.

Design and Installation Specifications:

- For mulch materials, application rates, and specifications see Table 4.7.

  Note: *Thicknesses may be increased for disturbed areas in or near sensitive areas or other areas highly susceptible to erosion.*

- Mulch seed within the ordinary high-water mark of surface waters should be selected to minimize potential flotation of organic matter. Composted organic materials have higher specific gravities (densities) than straw, wood, or chipped material.

Maintenance Standards:

- The thickness of the cover must be maintained.
- Any areas that experience erosion shall be remulched and/or protected with a net or blanket. If the erosion problem is drainage related, then the problem shall be fixed and the eroded area remulched.

BMP C122: Nets and Blankets

Purpose: Erosion control nets and blankets are intended to prevent erosion and hold seed and mulch in place on steep slopes and in channels so that vegetation can become well established. In addition, some nets and blankets can be used to permanently reinforce turf to protect drainage ways during high flows. Nets (commonly called matting) are strands of material woven into an open, but high-tensile strength net (for example, coconut fiber matting). Blankets are strands of material that are not tightly woven, but instead form a layer of interlocking fibers, typically held together by a biodegradable or photodegradable netting (for example, excelsior or straw blankets). They generally have lower tensile strength than nets, but cover the ground more completely. Coir (coconut fiber) fabric comes as both nets and blankets.

Conditions of Use: Erosion control nets and blankets should be used:

- To aid permanent vegetated stabilization of slopes 2H:1V or greater and with more than 10 feet of vertical relief.
- For drainage ditches and swales (highly recommended). The application of appropriate netting or blanket to drainage ditches and swales can protect bare soil from channelized runoff while vegetation is established. Nets and blankets also can capture a great deal of sediment due to their open, porous structure. Synthetic nets and blankets can be used to permanently stabilize channels and may provide a cost-effective, environmentally preferable alternative to riprap. 100 percent synthetic blankets manufactured for use in ditches may be easily reused as temporary ditch liners.

Disadvantages of blankets include:

- Surface preparation required;
- On slopes steeper than 2.5:1, blanket installers may need to be roped and harnessed for safety;
- They cost at least $4,000-6,000 per acre installed.

Advantages of blankets include:

- Can be installed without mobilizing special equipment;
- Can be installed by anyone with minimal training;
- Can be installed in stages or phases as the project progresses;
- Seed and fertilizer can be hand-placed by the installers as they progress down the slope;
- Can be installed in any weather;
- There are numerous types of blankets that can be designed with various parameters in mind. Those parameters include: fiber blend, mesh strength, longevity, biodegradability, cost, and availability.

Design and Installation Specifications:

- See Figure 7.3.4 and Figure 7.3.5 for typical orientation and installation of blankets used in channels and as slope protection. Note: these are typical only; all blankets must be installed per manufacturer's installation instructions.
- Installation is critical to the effectiveness of these products. If good ground contact is not achieved, runoff can concentrate under the product, resulting in significant erosion.
- Installation of Blankets on Slopes:
  1. Complete final grade and track walk up and down the slope.
  2. Install hydromulch with seed and fertilizer.
  3. Dig a small trench, approximately 12 inches wide by 6 inches deep along the top of the slope.
  4. Install the leading edge of the blanket into the small trench and staple approximately every 18 inches. NOTE: Staples are metal, "U"-shaped, and a minimum of 6 inches long. Longer staples are used in sandy soils. Biodegradable stakes are also available.
  5. Roll the blanket slowly down the slope as installer walks backwards. NOTE: The blanket rests against the installer's legs. Staples are installed as the blanket is unrolled. It is critical that the proper staple pattern is used for the blanket being installed. The blanket is not to be allowed to roll down the slope on its own as this stretches the blanket making it impossible to maintain soil contact. In addition, no one is allowed to walk on the blanket after it is in place.
  6. If the blanket is not long enough to cover the entire slope length, the trailing edge of the upper blanket should overlap the leading edge of the lower blanket and be stapled. On steeper slopes, this overlap should be installed in a small trench, stapled, and covered with soil.
- With the variety of products available, it is impossible to cover all the details of appropriate use and installation. Therefore, it is critical that the design engineer consults the manufacturer's information and that a site visit takes place in order to insure that the product specified is appropriate. Information is also available at the following web sites:

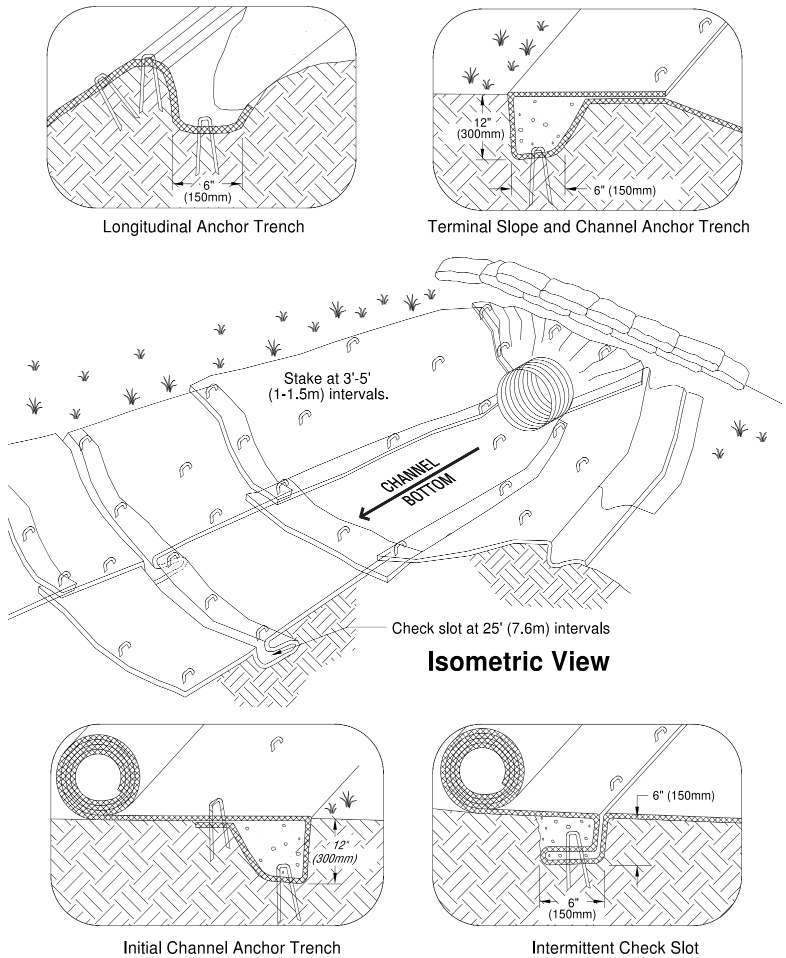
  WSDOT: http://www.wsdot.wa.gov/environment/wqec/erosion.htm

  Texas Transportation Institute:
  http://www.dot.state.tx.us/insdtdot/orgchart/cmd/erosion/contents.htm
- Jute matting must be used in conjunction with mulch (BMP C121). Excelsior, woven straw blankets and coir (coconut fiber) blankets may be installed without mulch. There are many other types of erosion control nets and blankets on the market that may be appropriate in certain circumstances.

- In general, most nets (e.g., jute matting) require mulch in order to prevent erosion because they have a fairly open structure. Blankets typically do not require mulch because they usually provide complete protection of the surface.
- Extremely steep, unstable, wet, or rocky slopes are often appropriate candidates for use of synthetic blankets, as are riverbanks, beaches and other high-energy environments. If synthetic blankets are used, the soil should be hydromulched first.
- 100 percent biodegradable blankets are available for use in sensitive areas. These organic blankets are usually held together with a paper or fiber mesh and stitching which may last up to a year.
- Most netting used with blankets is photodegradable, meaning they break down under sunlight (not UV stabilized). However, this process can take months or years even under bright sun. Once vegetation is established, sunlight does not reach the mesh. It is not uncommon to find non-degraded netting still in place several years after installation. This can be a problem if maintenance requires the use of mowers or ditch cleaning equipment. In addition, birds and small animals can become trapped in the netting.

Maintenance Standards:

- Good contact with the ground must be maintained, and erosion must not occur beneath the net or blanket.
- Any areas of the net or blanket that are damaged or not in close contact with the ground shall be repaired and stapled.
- If erosion occurs due to poorly controlled drainage, the problem shall be fixed and the eroded area protected.



NOTES:
1. Check slots to be constructed per manufacturers specifications.
2. Staking or stapling layout per manufacturers specifications.

Figure 7.3.4 - Channel

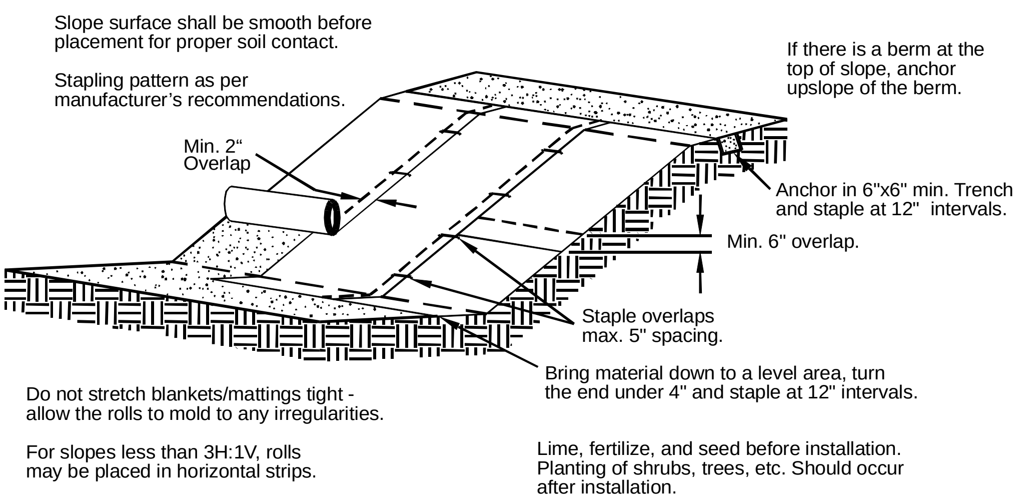


Figure 7.3.5 - Slope Installation

BMP C123: Plastic Covering

Purpose: Plastic covering provides immediate, short-term erosion protection to slopes and disturbed areas.

Conditions of Use:

- Plastic covering may be used on disturbed areas that require cover measures for less than 30 days, except as stated below.
- Plastic is particularly useful for protecting cut and fill slopes and stockpiles. Note: The relatively rapid breakdown of most polyethylene sheeting makes it unsuitable for long-term (greater than six months) applications.
- Clear plastic sheeting can be used over newly-seeded areas to create a greenhouse effect and encourage grass growth if the hydroseed was installed too late in the season to establish 75 percent grass cover, or if the wet season started earlier than normal. Clear plastic should not be used for this purpose during the summer months because the resulting high temperatures can kill the grass.
- Due to rapid runoff caused by plastic sheeting, this method shall not be used upslope of areas that might be adversely impacted by concentrated runoff. Such areas include steep and/or unstable slopes.
- While plastic is inexpensive to purchase, the added cost of installation, maintenance, removal, and disposal make this an expensive material, up to $1.50-2.00 per square yard.
- Whenever plastic is used to protect slopes, water collection measures must be installed at the base of the slope. These measures include plastic-covered berms, channels, and pipes used to covey clean rainwater away from bare soil and disturbed areas. At no time is clean runoff from a plastic covered slope to be mixed with dirty runoff from a project.
- Other uses for plastic include:
    - Temporary ditch liner;
    - Pond liner in temporary sediment pond;
    - Liner for bermed temporary fuel storage area if plastic is not reactive to the type of fuel being stored;
    - Emergency slope protection during heavy rains; and,
    - Temporary drainpipe (“elephant trunk”) used to direct water.

Design and Installation Specifications:

- Plastic slope cover must be installed as follows:
    1. Run plastic up and down slope, not across slope;
    2. Plastic may be installed perpendicular to a slope if the slope length is less than 10 feet;

3. Minimum of 8-inch overlap at seams;
4. On long or wide slopes, or slopes subject to wind, all seams should be taped;
5. Place plastic into a small (12-inch wide by 6-inch deep) slot trench at the top of the slope and backfill with soil to keep water from flowing underneath;
6. Place sand filled burlap or geotextile bags every 3 to 6 feet along seams and pound a wooden stake through each to hold them in place;
7. Inspect plastic for rips, tears, and open seams regularly and repair immediately. This prevents high velocity runoff from contacting bare soil which causes extreme erosion;
8. Sandbags may be lowered into place tied to ropes. However, all sandbags must be staked in place.

- Plastic sheeting shall have a minimum thickness of 0.06 millimeters.
- If erosion at the toe of a slope is likely, a gravel berm, riprap, or other suitable protection shall be installed at the toe of the slope in order to reduce the velocity of runoff.

Maintenance Standards:

- Torn sheets must be replaced and open seams repaired.
- If the plastic begins to deteriorate due to ultraviolet radiation, it must be completely removed and replaced.
- When the plastic is no longer needed, it shall be completely removed.
- Dispose of old tires appropriately.

BMP C124: Sodding

Purpose: The purpose of sodding is to establish permanent turf for immediate erosion protection and to stabilize drainage ways where concentrated overland flow will occur.

Conditions of Use: Sodding may be used in the following areas:

- Disturbed areas that require short-term or long-term cover.
- Disturbed areas that require immediate vegetative cover.
- All waterways that require vegetative lining. Waterways may also be seeded rather than sodded, and protected with a net or blanket.

Design and Installation Specifications:

- Sod shall be free of weeds, of uniform thickness (approximately 1-inch thick), and shall have a dense root mat for mechanical strength.
- The following steps are recommended for sod installation:
- Shape and smooth the surface to final grade in accordance with the approved grading plan. The swale needs to be overexcavated 4 to 6 inches below design elevation to allow room for placing soil amendment and sod.
- Amend 4 inches (minimum) of compost into the top 8 inches of the soil if the organic content of the soil is less than ten percent or the permeability is less than 0.6 inches per hour. Compost used should meet Ecology publication 98-3894-038 specifications for Grade A quality compost.
- Fertilize according to the supplier's recommendations.
- Work lime and fertilizer 1 to 2 inches into the soil, and smooth the surface.
- Lay strips of sod beginning at the lowest area to be sodded and perpendicular to the direction of water flow. Wedge strips securely into place. Square the ends of each strip to provide for a close, tight fit. Stagger joints at least 12 inches. Staple on slopes steeper than 3H:1V. Staple the upstream edge of each sod strip.
- Roll the sodded area and irrigate.
- When sodding is carried out in alternating strips or other patterns, seed the areas between the sod immediately after sodding.

Maintenance Standards:

- If the grass is unhealthy, the cause shall be determined and appropriate action taken to reestablish a healthy groundcover. If it is impossible to establish a healthy groundcover due to frequent saturation, instability, or some other cause, the sod shall be removed, the area seeded with an appropriate mix, and protected with a net or blanket.

BMP C125: Topsoiling

Purpose: To provide a suitable growth medium for final site stabilization with vegetation. While not a permanent cover practice in itself, topsoiling is an integral component of providing permanent cover in those areas where there is an unsuitable soil surface for plant growth. Native soils and disturbed soils that have been organically amended not only retain much more stormwater, but they also serve as effective biofilters for urban pollutants and, by supporting more vigorous plant growth, reduce the water, fertilizer and pesticides needed to support installed landscapes. Topsoil does not include any subsoils but only the material from the top several inches including organic debris.

Conditions of Use:

- Native soils should be left undisturbed to the maximum extent practicable. Native soils disturbed during clearing and grading should be restored, to the maximum extent practicable, to a condition where moisture-holding capacity is equal to or better than the original site conditions. This criterion can be met by using on-site native topsoil, incorporating amendments into on-site soil, or importing blended topsoil.
- Topsoiling is a required procedure when establishing vegetation on shallow soils, and soils of critically low pH (high acid) levels.
- Stripping of existing, properly functioning soil system and vegetation for the purpose of topsoiling during construction is not acceptable. If an existing soil system is functioning properly it shall be preserved in its undisturbed and uncompacted condition.
- Depending on where the topsoil comes from, or what vegetation was on site before disturbance, invasive plant seeds may be included and could cause problems for establishing native plants, landscaped areas, or grasses.
- Topsoil from the site will contain mycorrhizal bacteria that are necessary for healthy root growth and nutrient transfer. These native mycorrhiza are acclimated to the site and will provide optimum conditions for establishing grasses. Commercially available mycorrhiza products should be used when topsoil is brought in from off-site.

Design and Installation Specifications: If topsoiling is to be done, the following items should be considered:

- Maximize the depth of the topsoil wherever possible to provide the maximum possible infiltration capacity and beneficial growth medium. Topsoil depth shall be at least 8 inches with a minimum organic content of 10 percent dry weight and pH between 6.0 and 8.0 or matching the pH of the undisturbed soil. This can be accomplished either by returning native topsoil to the site and/or incorporating organic amendments. Organic amendments should be incorporated to a minimum 8-inch depth except where tree roots or other natural features limit the depth of incorporation. Subsoils below the 12-inch depth should be scarified at least 2 inches to avoid stratified layers, where feasible. The decision to either layer topsoil over a subgrade or incorporate topsoil into the underlying layer may vary depending on the planting specified.

- If blended topsoil is imported, then fines should be limited to 25 percent passing through a 200 sieve.
- The final composition and construction of the soil system will result in a natural selection or favoring of certain plant species over time. For example, recent practices have shown that incorporation of topsoil may favor grasses, while layering with mildly acidic, high-carbon amendments may favor more woody vegetation.
- Locate the topsoil stockpile so that it meets specifications and does not interfere with work on the site. It may be possible to locate more than one pile in proximity to areas where topsoil will be used.
- Allow sufficient time in scheduling for topsoil to be spread prior to seeding, sodding, or planting.
- Care must be taken not to apply to subsoil if the two soils have contrasting textures. Sandy topsoil over clayey subsoil is a particularly poor combination, as water creeps along the junction between the soil layers and causes the topsoil to slough.
- If topsoil and subsoil are not properly bonded, water will not infiltrate the soil profile evenly and it will be difficult to establish vegetation. The best method to prevent a lack of bonding is to actually work the topsoil into the layer below for a depth of at least 6 inches.
- Ripping or re-structuring the subgrade may also provide additional benefits regarding the overall infiltration and interflow dynamics of the soil system.
- Field exploration of the site shall be made to determine if there is surface soil of sufficient quantity and quality to justify stripping. Topsoil shall be friable and loamy (loam, sandy loam, silt loam, sandy clay loam, clay loam). Areas of natural ground water recharge should be avoided.
- Stripping shall be confined to the immediate construction area. A 4- to 6-inch stripping depth is common, but depth may vary depending on the particular soil. All surface runoff control structures shall be in place prior to stripping.

One way of stockpiling topsoil is as follows:

- Side slopes of the stockpile shall not exceed 2:1.
- An interceptor dike with gravel outlet and silt fence should surround all topsoil stockpiles between October 1 and April 30. Between May 1 and September 30, an interceptor dike with gravel outlet and silt fence shall be installed if the stockpile will remain in place for a longer period of time than active construction grading.

- Erosion control seeding or covering with clear plastic or other mulching materials of stockpiles should be completed within 7 days (October 1 through April 30) or 30 days (May 1 through September 30) of the formation of the stockpile. Native topsoil stockpiles shall not be covered with plastic.
- Topsoil shall not be placed while in a frozen or muddy condition, when the subgrade is excessively wet, or when conditions exist that may otherwise be detrimental to proper grading or proposed sodding or seeding.
- Previously established grades on the areas to be topsoiled shall be maintained according to the approved plan.
- When native topsoil is to be stockpiled and reused the following should apply to ensure that the mycorrhizal bacterial, earthworms, and other beneficial organisms will not be destroyed:
  1. Topsoil is to be re-installed within 4 to 6 weeks;
  2. Topsoil is not to become saturated with water;
  3. Plastic cover is not allowed.

Maintenance Standards:

- Inspect stockpiles regularly, especially after large storm events. Stabilize any areas that have eroded.

BMP C126: Polyacrylamide for Soil Erosion Protection

Purpose: Polyacrylamide (PAM) is used on construction sites to prevent soil erosion.

Applying PAM to bare soil in advance of a rain event significantly reduces erosion and controls sediment in two ways. First, PAM increases the soil's available pore volume, thus increasing infiltration through flocculation and reducing the quantity of stormwater runoff. Second, it increases flocculation of suspended particles and aids in their deposition, thus reducing stormwater runoff turbidity and improving water quality.

Conditions of Use

Conditions of Use: PAM shall not be directly applied to water or allowed to enter a water body. In areas that drain to a sediment pond, PAM can be applied to bare soil under the following conditions:

- During rough grading operations.
- Staging areas.
- Balanced cut and fill earthwork.
- Haul roads prior to placement of crushed rock surfacing.
- Compacted soil roadbase.
- Stockpiles.
- After final grade and before paving or final seeding and planting.
- Pit sites.

Sites having a winter shut down. In the case of winter shut down, or where soil will remain unworked for several months, PAM should be used together with mulch.

Design and Installation Specifications: PAM may be applied in dissolved form with water, or it may be applied in dry, granular or powdered form. The preferred application method is the dissolved form.

PAM is to be applied at a maximum rate of ½ pound PAM per 1000 gallons water per 1 acre of bare soil. Table 7.3.8 and Figure 7.3.6 can be used to determine the PAM and water application rate for a disturbed soil area. Higher concentrations of PAM do not provide any additional effectiveness.

Table 7.3.8
PAM and Water Application Rates

Disturbed Area (ac)	PAM (lbs)	Water (gal)
0.50	0.25	500
1.00	0.50	1,000
1.50	0.75	1,500
2.00	1.00	2,000
2.50	1.25	2,500
3.00	1.50	3,000
3.50	1.75	3,500
4.00	2.00	4,000
4.50	2.25	4,500
5.00	2.50	5,000

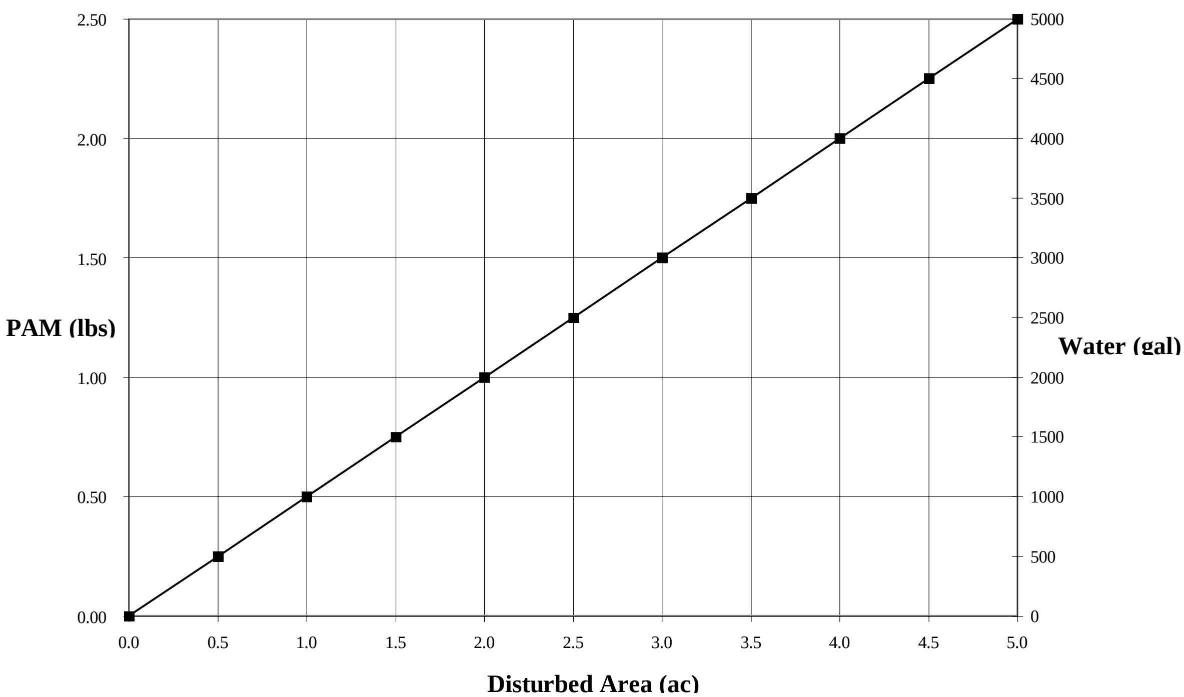


Figure 7.3.6 - PAM and Water Application

The Preferred Method:

- Pre-measure the area where PAM is to be applied and calculate the amount of product and water necessary to provide coverage at the specified application rate (1/2 pound PAM/1000 gallons/acre).
- PAM has infinite solubility in water, but dissolves very slowly. Dissolve pre-measured dry granular PAM with a known quantity of clean water in a bucket several hours or overnight. Mechanical mixing will help dissolve the PAM. Always add PAM to water - not water to PAM.
- Pre-fill the water truck about 1/8 full with water. The water does not have to be potable, but it must have relatively low turbidity – in the range of 20 NTU or less.
- Add PAM /Water mixture to the truck
- Completely fill the water truck to specified volume.
- Spray PAM/Water mixture onto dry soil until the soil surface is uniformly and completely wetted.

An Alternate Method:

PAM may also be applied as a powder at the rate of 5 lbs. per acre. This must be applied on a day that is dry. For areas less than 5-10 acres, a hand-held “organ grinder” fertilizer spreader set to the smallest setting will work. Tractor-mounted spreaders will work for larger areas.

The following shall be used for application of PAM:

- PAM shall be used in conjunction with other BMPs and not in place of other BMPs.
- Do not use PAM on a slope that flows directly into a stream or wetland. The stormwater runoff shall pass through a sediment control BMP prior to discharging to surface waters.
- Do not add PAM to water discharging from site.
- When the total drainage area is greater than or equal to 5 acres, PAM treated areas shall drain to a sediment pond.
- Areas less than 5 acres shall drain to sediment control BMPs, such as a minimum of 3 check dams per acre. The total number of check dams used shall be maximized to achieve the greatest amount of settlement of sediment prior to discharging from the site. Each check dam shall be spaced evenly in the drainage channel through which stormwater flows are discharged off-site.
- On all sites, the use of silt fence shall be maximized to limit the discharges of sediment from the site.

- All areas not being actively worked shall be covered and protected from rainfall. PAM shall not be the only cover BMP used.
- PAM can be applied to wet soil, but dry soil is preferred due to less sediment loss.
- PAM will work when applied to saturated soil but is not as effective as applications to dry or damp soil.
- Keep the granular PAM supply out of the sun. Granular PAM loses its effectiveness in three months after exposure to sunlight and air.
- Proper application and re-application plans are necessary to ensure total effectiveness of PAM usage.
- PAM, combined with water, is very slippery and can be a safety hazard. Care must be taken to prevent spills of PAM powder onto paved surfaces. During an application of PAM, prevent over-spray from reaching pavement as pavement will become slippery. If PAM powder gets on skin or clothing, wipe it off with a rough towel rather than washing with water-this only makes cleanup messier and take longer.
- Some PAMs are more toxic and carcinogenic than others. Only the most environmentally safe PAM products should be used.

The specific PAM copolymer formulation must be anionic. Cationic PAM shall not be used in any application because of known aquatic toxicity problems. Only the highest drinking water grade PAM, certified for compliance with ANSI/NSF Standard 60 for drinking water treatment, will be used for soil applications. Recent media attention and high interest in PAM has resulted in some entrepreneurial exploitation of the term "polymer." All PAM are polymers, but not all polymers are PAM, and not all PAM products comply with ANSI/NSF Standard 60. PAM use shall be reviewed and approved by the jurisdiction. The Washington State Department of Transportation (WSDOT) has listed approved PAM products on their web page.

- PAM designated for these uses should be "water soluble" or "linear" or "non-crosslinked". Cross-linked or water absorbent PAM, polymerized in highly acidic (pH<2) conditions, are used to maintain soil moisture content.
- The PAM anionic charge density may vary from 2-30 percent; a value of 18 percent is typical. Studies conducted by the United States Department of Agriculture (USDA)/ARS demonstrated that soil stabilization was optimized by using very high molecular weight (12-15 mg/mole), highly anionic (>20% hydrolysis) PAM.
- PAM tackifiers are available and being used in place of guar and alpha plantago. Typically, PAM tackifiers should be used at a rate of no more than 0.5-1 lb. per 1000 gallons of water in a hydromulch machine. Some tackifier product instructions say to use at a rate of 3 –5 lbs. per acre, which can be too much. In addition, pump problems can occur at higher rates due to increased viscosity.

Maintenance Standards: PAM may be reapplied on actively worked areas after a 48-hour period.

- Reapplication is not required unless PAM treated soil is disturbed or unless turbidity levels show the need for an additional application. If PAM treated soil is left undisturbed a reapplication may be necessary after two months. More PAM applications may be required for steep slopes, silty and clayey soils (USDA Classification Type “C” and “D” soils), long grades, and high precipitation areas. When PAM is applied first to bare soil and then covered with straw, a reapplication may not be necessary for several months.
- Loss of sediment and PAM may be a basis for penalties per RCW 90.48.080.

BMP C130: Surface Roughening

Purpose: Surface roughening aids in the establishment of vegetative cover, reduces runoff velocity, increases infiltration, and provides for sediment trapping through the provision of a rough soil surface. Horizontal depressions are created by operating a tiller or other suitable equipment on the contour or by leaving slopes in a roughened condition by not fine grading them.

Conditions for Use:

- All slopes steeper than 3:1 and greater than 5 vertical feet require surface roughening.
- Areas with grades steeper than 3:1 should be roughened to a depth of 2 to 4 inches prior to seeding.
- Areas that will not be stabilized immediately may be roughened to reduce runoff velocity until seeding takes place.
- Slopes with a stable rock face do not require roughening.
- Slopes where mowing is planned should not be excessively roughened.

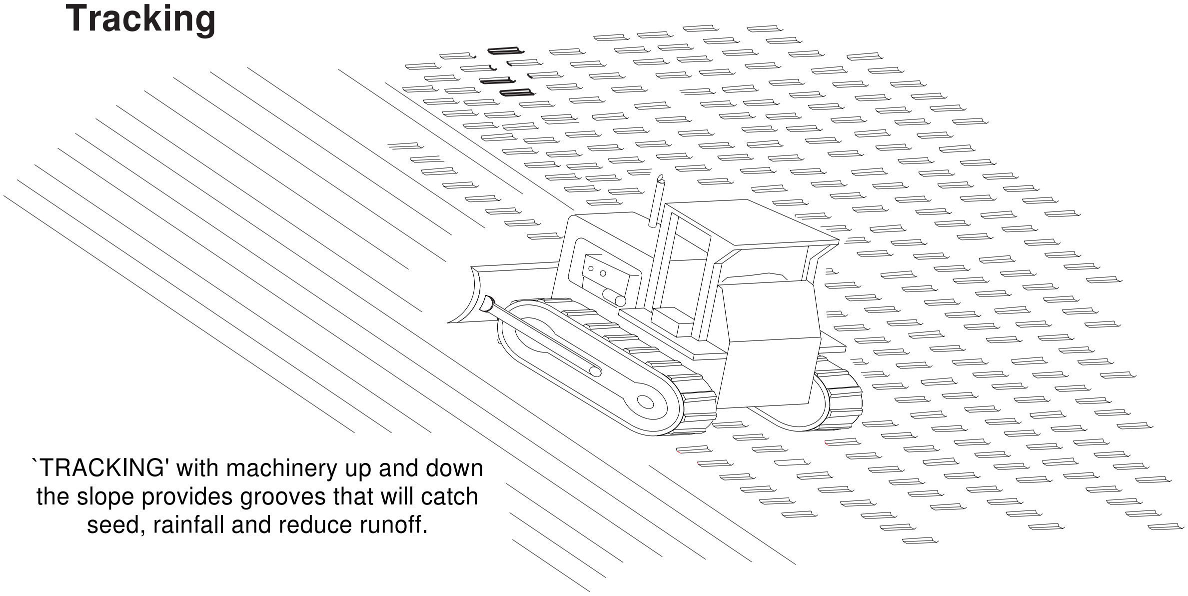
Design and Installation Specifications:

- There are different methods for achieving a roughened soil surface on a slope, and the selection of an appropriate method depends upon the type of slope. Roughening methods include stair-step grading, grooving, contour furrows, and tracking. See Figure 7.3.7 for tracking and contour furrows. Factors to be considered in choosing a method are slope steepness, mowing requirements, and whether the slope is formed by cutting or filling.
- Disturbed areas that will not require mowing may be stair-step graded, grooved, or left rough after filling.
- Stair-step grading is particularly appropriate in soils containing large amounts of soft rock. Each “step” catches material that sloughs from above, and provides a level site where vegetation can become established. Stairs should be wide enough to work with standard earth moving equipment. Stair steps must be on contour or gullies will form on the slope.
- Areas that will be mowed (these areas should have slopes less steep than 3:1) may have small furrows left by disking, harrowing, raking, or seed-planting machinery operated on the contour.
- Graded areas with slopes greater than 3:1 but less than 2:1 should be roughened before seeding. This can be accomplished in a variety of ways, including “track walking,” or driving a crawler tractor up and down the slope, leaving a pattern of cleat imprints parallel to slope contours.
- Tracking is done by operating equipment up and down the slope to leave horizontal depressions in the soil.

Maintenance Standards: Areas that are graded in this manner should be seeded as quickly as possible.

- Regular inspections should be made of the area. If rills appear, they should be re-graded and re-seeded immediately.

Tracking



Contour Furrows

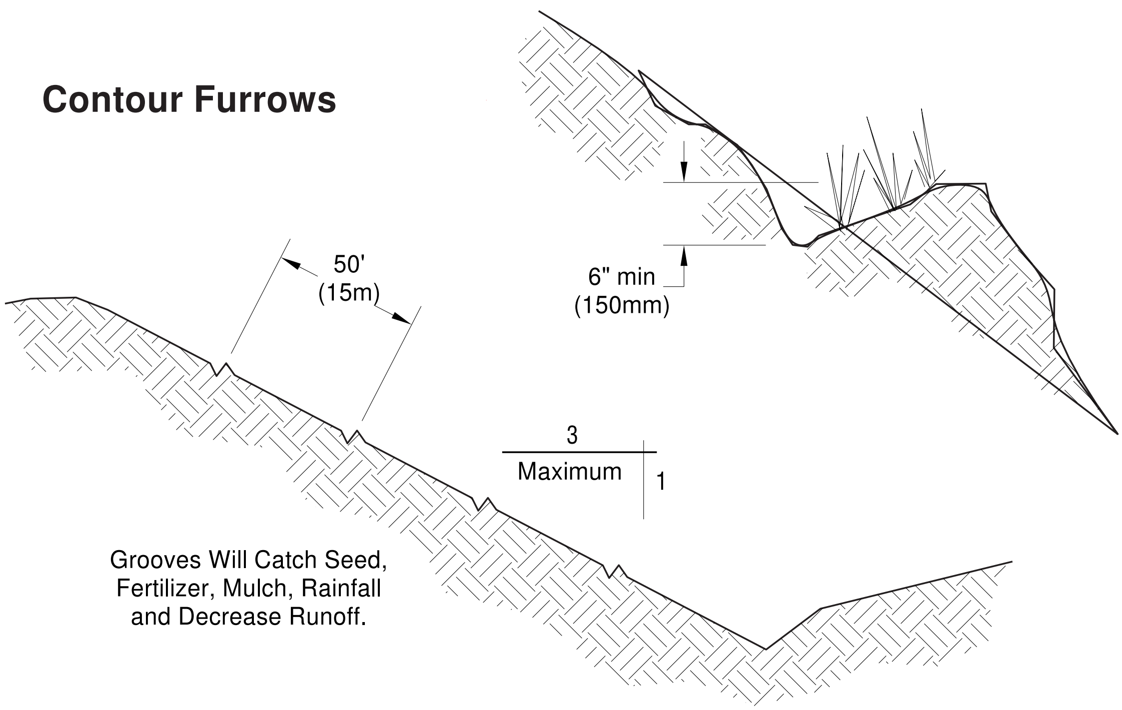


Figure 7.3.7 - Tracking and Contour Furrows

BMP C131: Gradient Terraces

Purpose: Gradient terraces reduce erosion damage by intercepting surface runoff and conducting it to a stable outlet at a non-erosive velocity.

Conditions for Use: Gradient terraces normally are limited to denuded land having a water erosion problem. They should not be constructed on deep sands or on soils that are too stony, steep, or shallow to permit practical and economical installation and maintenance. Gradient terraces may be used only where suitable outlets are or will be made available. See Figure 7.3.8 for gradient terraces.

Design and Installation Specifications:

- The maximum spacing of gradient terraces should be determined by the following method:

  VI = (0.8)s + y

  Where:

  VI = vertical interval in feet
  s = land rise per 100 feet, expressed in feet
  y = a soil and cover variable with values from 1.0 to 4.0

  Values of “y” are influenced by soil erodibility and cover practices. The lower values are applicable to erosive soils where little to no residue is left on the surface. The higher value is applicable only to erosion-resistant soils where a large amount of residue (1½ tons of straw/acre equivalent) is on the surface.

- The minimum constructed cross-section should meet the design dimensions.

- The top of the constructed ridge should not be lower at any point than the design elevation plus the specified overfill for settlement The opening at the outlet end of the terrace should have a cross section equal to that specified for the terrace channel.

- Channel grades may be either uniform or variable with a maximum grade of 0.6 feet per 100 feet length. For short distances, terrace grades may be increased to improve alignment. The channel velocity should not exceed that which is nonerosive for the soil type with the planned treatment.

- All gradient terraces should have adequate outlets. Such an outlet may be a grassed waterway, vegetated area, or tile outlet. In all cases the outlet must convey runoff from the terrace or terrace system to a point where the outflow will not cause damage. Vegetative cover should be used in the outlet channel.

- The design elevation of the water surface of the terrace should not be lower than the design elevation of the water surface in the outlet at their junction, when both are operating at design flow.

- Vertical spacing determined by the above methods may be increased as much as 0.5 feet or 10 percent, whichever is greater, to provide better alignment or location, to avoid obstacles, to adjust for equipment size, or to reach a satisfactory outlet.

- **The drainage area above the top should not exceed the area that would be drained by a terrace with normal spacing.**
- The terrace should have enough capacity to handle the peak runoff expected from a 2-year, 24-hour design storm without overtopping.
- The terrace cross-section should be proportioned to fit the land slope. The ridge height should include a reasonable settlement factor. The ridge should have a minimum top width of 3 feet at the design height. The minimum cross-sectional area of the terrace channel should be 8 square feet for land slopes of 5 percent or less, 7 square feet for slopes from 5 to 8 percent, and 6 square feet for slopes steeper than 8 percent. The terrace can be constructed wide enough to be maintained using a small cat.

Maintenance Standards

- Maintenance should be performed as needed. Terraces should be inspected regularly; at least once a year, and after large storm events.

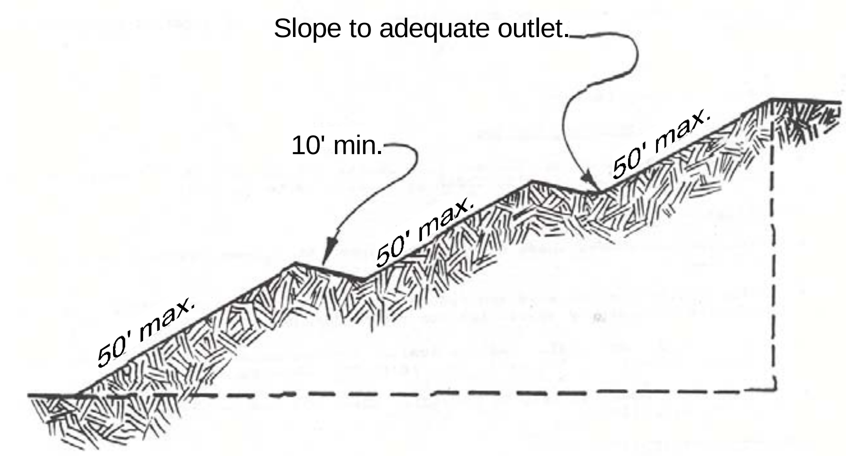


Figure 7.3.8 - Gradient Terraces

BMP C140: Dust Control

Purpose: Dust control prevents wind transport of dust from disturbed soil surfaces onto roadways, drainage ways, and surface waters. Wind erosion is a significant cause of soil movement from construction sites in Eastern Washington. Although wind erosion can contribute to water quality impacts, dust control is regulated in some areas of Eastern Washington primarily through local air quality authorities. Where such an entity exists, contact the local air quality authority for appropriate and required BMPs for dust control to implement at your project site.

Conditions for Use: In areas (including roadways) subject to surface and air movement of dust where on-site and off-site impacts to roadways, drainage ways, or surface waters are likely.

Design and Installation Specifications:

- Contact your local Air Pollution Control Authority for guidance and training on other dust control measures. Compliance with the local Air Pollution Control Authority constitutes compliance with this BMP.
- Water applied to construction sites for dust control must not leave the site as surface runoff.
- See also "Techniques for Dust Prevention and Suppression," Ecology Publication Number 96-433, revised April 2002.
- Techniques that can be used for construction projects include:
- Vegetate or mulch areas that will not receive vehicle traffic. In areas where planting, mulching, or paving is impractical, apply gravel or landscaping rock.
- Limit dust generation by clearing only those areas where immediate activity will take place, leaving the remaining area(s) in the original condition, if stable. Maintain the original ground cover as long as practical.
- Construct natural or artificial windbreaks or windscreens. These may be designed as enclosures for small dust sources.
- Sprinkle the site with water until surface is wet. Repeat as needed. To prevent carryout of mud onto street, refer to Stabilized Construction Entrance (BMP C105).
- Irrigation water can be used for dust control. Irrigation systems should be installed as a first step on sites where dust control is a concern.
- Spray exposed soil areas with a dust palliative, following the manufacturer's instructions and cautions regarding handling and application. Used oil is prohibited from use as a dust suppressant. Local governments may approve other dust palliatives such as calcium chloride or PAM.
- PAM (BMP C126) added to water at a rate of 0.5 lbs. per 1,000 gallons of water per acre and applied from a water truck is more effective than water

alone. This is due to the increased infiltration of water into the soil and reduced evaporation. In addition, small soil particles are bonded together and are not as easily transported by wind. Adding PAM may actually reduce the quantity of water needed for dust control, especially in eastern Washington. Since the wholesale cost of PAM is about $ 4.00 per pound, this is an extremely cost-effective dust control method.

Techniques that can be used for unpaved roads and lots include:

- Lower speed limits. High vehicle speed increases the amount of dust stirred up from unpaved roads and lots.
- Upgrade the road surface strength by improving particle size, shape, and mineral types that make up the surface and base materials.
- Add surface gravel to reduce the source of dust emission. Limit the amount of fine particles (those smaller than .075 mm) to 10 to 20 percent.
- Use geotextile fabrics to increase the strength of new roads or roads undergoing reconstruction.
- Encourage the use of alternate, paved routes, if available.
- Restrict use by tracked vehicles and heavy trucks to prevent damage to road surface and base.
- Apply chemical dust suppressants using the admix method, blending the product with the top few inches of surface material. Suppressants may also be applied as surface treatments.
- Pave unpaved permanent roads and other trafficked areas.
- Use vacuum street sweepers.
- Remove mud and other dirt promptly so it does not dry and then turn into dust.
- Limit dust-causing work on windy days.

Maintenance Standards:

- Respray area as necessary to keep dust to a minimum. Water applied to construction sites for dust control must not leave the site as surface runoff.

BMP C150: Materials On Hand

Purpose: Quantities of erosion prevention and sediment control materials can be kept on the project site at all times to be used for emergency situations such as unexpected heavy summer rains. Having these materials on-site reduces the time needed to implement BMPs when inspections indicate that existing BMPs are not meeting the Construction SWPPP requirements. In addition, contractors can save money by buying some materials in bulk and storing them at their office or yard.

Conditions for Use:

- Construction projects of any size or type can benefit from having materials on hand. A small commercial development project could have a roll of plastic and some gravel available for immediate protection of bare soil and temporary berm construction. A large earthwork project, such as highway construction, might have several tons of straw, several rolls of plastic, flexible pipe, sandbags, geotextile fabric and steel "T" posts.
- Materials are stockpiled and readily available before any site clearing, grubbing, or earthwork begins. A large contractor or developer could keep a stockpile of materials that are available to be used on several projects.
- If storage space at the project site is at a premium, the contractor could maintain the materials at their office or yard. The office or yard must be less than an hour from the project site.

Design and Installation Specifications: Depending on project type, size, complexity, and length, materials and quantities will vary. A good minimum that will cover numerous situations includes:

Material	Measure	Quantity
Clear Plastic, 6 mil	100 foot roll	1-2
Drainpipe, 6 or 8 inch diameter	25 foot section	4-6
Sandbags, filled	each	25-50
Straw Bales for mulching,	approx. 50# each	10-20
Quarry Spalls	ton	2-4
Washed Gravel	cubic yard	2-4
Geotextile Fabric	100 foot roll	1-2
Catch Basin Inserts	each	2-4
Steel "T" Posts	each	12-24

Maintenance Standards:

- All materials with the exception of the quarry spalls, steel "T" posts, and gravel should be kept covered and out of both sun and rain.
- Re-stock materials used as needed.

BMP C151: Concrete Handling

Purpose: Concrete work can generate process water and slurry that contain fine particles and high pH, both of which can violate water quality standards in the receiving water. This BMP is intended to minimize and eliminate concrete process water and slurry from entering waters of the state.

Conditions for Use: Any time concrete is used, these management practices shall be utilized. Concrete construction projects include, but are not limited to, the following:

- Curbs
- Sidewalks
- Roads
- Bridges
- Foundations
- Floors
- Runways

Design and Installation Specifications:

- Concrete truck chutes, pumps, and internals shall be washed out only into formed areas awaiting installation of concrete or asphalt.
- Unused concrete remaining in the truck and pump shall be returned to the originating batch plant for recycling.
- Hand tools including, but not limited to, screeds, shovels, rakes, floats, and trowels shall be washed off only into formed areas awaiting installation of concrete or asphalt.
- Equipment that cannot be easily moved, such as concrete pavers, shall only be washed in areas that do not directly drain to natural or constructed stormwater conveyances.
- Washdown from areas such as concrete aggregate driveways shall not drain directly to natural or constructed stormwater conveyances.
- When no formed areas are available, washwater and leftover product shall be contained in a lined container. Contained concrete shall be disposed of in a manner that does not violate groundwater or surface water quality standards.

Maintenance Standards:

- Containers shall be checked for holes in the liner daily during concrete pours and repaired the same day.

BMP C152: Sawcutting and Surfacing Pollution Prevention

Purpose: Sawcutting and surfacing operations generate slurry and process water that contain fine particles and high pH (concrete cutting), both of which can violate the water quality standards in the receiving water. This BMP is intended to minimize and eliminate process water and slurry from entering waters of the State.

Conditions for Use: Anytime sawcutting or surfacing operations take place, these management practices should be utilized. Sawcutting and surfacing operations include, but are not limited to, the following:

- Sawing
- Coring
- Grinding
- Roughening
- Hydro-demolition
- Bridge and road surfacing

Design and Installation Specifications:

- Slurry and cuttings should be vacuumed during cutting and surfacing operations.
- Slurry and cuttings should not remain on permanent concrete or asphalt pavement overnight.
- Slurry and cuttings should not drain to any natural or constructed drainage conveyance.
- Collected slurry and cuttings shall be disposed of in a manner that does not violate groundwater or surface water quality standards.
- Process water that is generated during hydro-demolition, surface roughening or similar operations should not drain to any natural or constructed drainage conveyance and shall be disposed of in a manner that does not violate groundwater or surface water quality standards.
- Cleaning waste material and demolition debris should be handled and disposed of in a manner that does not cause contamination of water. If the area is swept with a pick-up sweeper, the material should be hauled out of the area to an appropriate disposal site.

Maintenance Standards:

- Continually monitor operations to determine whether slurry, cuttings, or process water could enter waters of the state. If inspections show that a violation of water quality standards could occur, stop operations and immediately implement preventive measures such as berms, barriers, secondary containment, and vacuum trucks.

BMP C160: Contractor Erosion and Spill Control Lead

Purpose: The Contractor designates at least one person as the responsible representative in charge of erosion and spill control. The designated employee or contact shall be the Contractor Erosion and Spill Control Lead (CESCL) who is responsible for ensuring compliance with all local, State, and Federal erosion and sediment control requirements.

Conditions for Use: A CESCL should be made available on project types that include, but are not limited to, the following:

- Projects with an NPDES and State Waste Discharge Permit for Stormwater Discharges Associated with Construction Activities.
- Heavy construction of roads, bridges, highways, airports, buildings.
- Projects near wetlands and sensitive or critical areas.
- Projects in or over water.

Design and Installation Specifications: The CESCL shall be qualified in construction site erosion and sediment control regulatory requirements and BMPs:

- The CESCL shall have thorough knowledge and understanding of the Construction Stormwater Pollution Prevention Plan (SWPPP) for the project site.
- The CESCL shall have authority to act on behalf of the contractor or developer and shall be available, on call, 24 hours per day throughout the period of construction.
- The Construction SWPPP shall include the name, telephone number, fax number, and address of the designated CESCL. If the CESCL information is not available during initial SWPPP development, it should be noted in the narrative of the SWPPP. When the CESCL information becomes available to the owner/developer, it must be added to the SWPPP.
- The CESCL shall have up-to-date training and field experience in construction erosion and sediment control practices.
- The CESCL should have a current certificate proving attendance in the "Construction Site Erosion and Sediment Control Certification Course," offered throughout the year by the Associated General Contractors of Washington Education Foundation or a similar course or certification program such as:
    - WSDOT certification in Construction Site Erosion and Sediment Control.
    - Certified Professional in Erosion and Sediment Control (CPESC) offered by the International Erosion Control Association (IECA).

Duties and responsibilities of the CESCL shall include, but are not limited to the following:

- Maintaining permit file on site at all times which includes the SWPPP and any associated permits and plans.

- Directing BMP installation, inspection, maintenance, modification, and removal.
- Availability 24 hours per day, 7 days per week by telephone.
- Updating all project drawings and the Construction SWPPP with changes made.
- Keeping daily logs, and inspection reports. Inspection reports should include:
    - When, where and how BMPs were installed, removed, or modified.
    - Repairs needed or made.
    - Observations of BMP effectiveness and proper placement.
    - Recommendations for improving performance of BMPs.
    - Identify the points where storm water runoff potentially leaves the site, is collected in a surface water conveyance system (i.e., road ditch, storm sewer), and enters receiving waters of the state.
    - If water sheet flows from the site, identify the point at which it becomes concentrated in a collection system.
    - Inspect for SWPPP requirements including BMPs as required to ensure adequacy.
    - Facilitate, participate in, and take corrective actions resulting from inspections performed by outside agencies or the owner.

BMP C161: Payment of Erosion Control Work

Purpose: As with any construction operation, the contractor should be paid for erosion control work. Payment for erosion control must be addressed during project development and design. Method of payment should be identified in the SWPPP.

Conditions for Use: Erosion control work should never be "incidental" to the contract as it is extremely difficult for the contractor to bid the work. Work that is incidental to the contract is work where no separate measurement or payment is made. The cost for incidental work is included in payments made for applicable bid items in the Schedule of Unit Prices. For example, any erosion control work associated with an item called "Clearing and Grubbing" is bid and paid for as part of that item, not separately.

Several effective means for payment of erosion control work are described below. These include:

- Temporary Erosion and Sediment Control (TESC) Lump Sum.
- TESC-Force Account.
- Unit Prices.
- Lump Sum.

TESC Lump Sum

One good method for achieving effective erosion and sediment control is to set up a Progress Payment system whereby the contract spells out exactly what is expected and allows for monthly payments over the life of the contract.

For example, an Item called "TESC Lump Sum" is listed in the Bid Schedule of Unit Prices. An amount, such as $10,000, is written in both the Unit Price and Amount columns. This requires all bidders to bid $10,000 for the item. If $10,000 is not shown in the Amount column, each contractor bids the amount. Often this is under-bid, which can cause compliance difficulties later. In this example, the contractor is required to revise the project Construction SWPPP by developing a Contractor's Erosion and Sediment Control Plan (CESCP) that is specific to their operations.

Next, the following language is included in the TESC specification Payment section.

Based upon lump sum Bid Item "TESC Lump Sum", payments will be made as follows:

A. Upon receipt of the Contractor's CESCP, 25 percent.

B. After Notice To Proceed and before Substantial Completion, 50 percent will be pro rated and paid monthly for compliance with the CESCP. Non-compliance will result in withholding of payment for the month of non-compliance.

C. At Final Payment, 25 percent for a clean site.

Payment for "TESC Lump Sum" will be full compensation for furnishing all labor, equipment, materials and tools to implement the CESCP, install, inspect, maintain, and remove temporary erosion and sediment controls as detailed in the drawings and specified herein, with the exception of those items measured and paid for separately.

TESC Force Account

One good method for ensuring that contingency money is available to address unforeseen erosion and sediment control problems is to set up an item called "TESC-Force Account". For example, an amount such as $15,000 is written in both the Unit Price and Amount columns for the item. This requires all bidders to bid $15,000 for the item.

The Force Account is used only at the discretion of the contracting agency or developer. If there are no unforeseen erosion problems, the money is not used. If there are unforeseen erosion problems, the contracting agency would direct the work to be done and pay an agreed upon amount for the work (such as predetermined rates under a Time and Materials setting).

Contract language for this item could look like this:

> Measurement and Payment for "TESC-Force Account" will be on a Force Account basis in accordance with_________*(include appropriate section of the Contract Specifications).* The amount entered in the Schedule of Unit Prices is an estimate.

Unit Prices

When the material or work can be quantified, it can be paid by Unit Prices. For example, the project designer knows that 2 acres will need to be hydroseeded and sets up an Item of Work for Hydroseed, with a Bid Quantity of 2, and a Unit for Acre. The bidder writes in the unit Prices and Amount.

Unit Price items can be used in conjunction with TESC-Force Account and TESC-Lump Sum.

Lump Sum

In contracts where all the work in a project is paid as a Lump Sum, erosion control is usually not paid as a separate item. In order to ensure that appropriate amounts are bid into the contract, the contracting agency can request a Schedule of Values and require that all erosion control costs be identified.

BMP C162: Scheduling

Purpose: Sequencing a construction project reduces the amount and duration of soil exposed to erosion by wind, rain, runoff, and vehicle tracking.

Conditions for Use: The construction sequence schedule is an orderly listing of all major land-disturbing activities together with the necessary erosion and sedimentation control measures planned for the project. This type of schedule guides the contractor on work to be done before other work is started so that serious erosion and sedimentation problems can be avoided.

Following a specified work schedule that coordinates the timing of land-disturbing activities and the installation of control measures is perhaps the most cost-effective way of controlling erosion during construction. The removal of surface ground cover leaves a site vulnerable to accelerated erosion. Construction procedures that limit land clearing, provide timely installation of erosion and sedimentation controls, and restore protective cover quickly can significantly reduce the erosion potential of a site.

Design Considerations:

- Avoid rainy periods.
- Schedule projects to disturb only small portions of the site at any one time. Complete grading as soon as possible. Immediately stabilize the disturbed portion before grading the next portion. Practice staged seeding in order to revegetate cut and fill slopes as the work progresses.

BMP C180: Small Project Construction Stormwater Pollution Prevention

Purpose: To prevent the discharge of sediment and other pollutants to the maximum extent practicable from small construction projects.

Conditions for Use: On small construction projects, those adding or replacing less than 2,000 square feet of impervious surface or clearing less than 7,000 square feet.

Design Considerations:

- Plan and implement proper clearing and grading of the site. It is most important only to clear the areas needed, thus keeping exposed areas to a minimum. Phase clearing so that only those areas that are actively being worked are uncovered. Note: Clearing limits should be flagged in the lot or area prior to initiating clearing.
- Soil should be managed in a manner that does not permanently compact or deteriorate the final soil and landscape system. If disturbance and/or compaction occur the impact must be corrected at the end of the construction activity. This should include restoration of soil depth, soil quality, permeability, and percent organic matter. Construction practices must not cause damage to or compromise the design of permanent landscape or infiltration areas.
- Locate excavated basement soil a reasonable distance behind the curb, such as in the backyard or side yard area. This will increase the distance eroded soil must travel to reach the storm sewer system. Soil piles should be covered until the soil is either used or removed. Piles should be situated so that sediment does not run into the street or adjoining yards.
- Backfill basement walls as soon as possible and rough grade the lot. This will eliminate large soil mounds, which are highly erodible, and prepares the lot for temporary cover, which will further reduce erosion potential.
- Remove excess soil from the site as soon as possible after backfilling. This will eliminate any sediment loss from surplus fill.
- If a lot has a soil bank higher than the curb, a trench or berm should be installed moving the bank several feet behind the curb. This will reduce the occurrence of gully and rill erosion while providing a storage and settling area for stormwater.
- The construction entrance should be stabilized where traffic will be leaving the construction site and traveling on paved roads or other paved areas within 1,000 feet of the site.
- Provide for periodic street cleaning to remove any sediment that may have been tracked out. Sediment should be removed by shoveling or sweeping

and carefully removed to a suitable disposal area where it will not be re-eroded.

- Utility trenches that run up and down slopes should be backfilled within seven days. Cross-slope trenches may remain open throughout construction to provide runoff interception and sediment trapping, provided that they do not convey turbid runoff off site.

7.3.2 Runoff Conveyance and Treatment BMPs

BMP C200: Interceptor Dike and Swale

Purpose: Provide a ridge of compacted soil, or a ridge with an upslope swale, at the top or base of a disturbed slope or along the perimeter of a disturbed construction area to convey stormwater. Use the dike and/or swale to intercept the runoff from unprotected areas and direct it to areas where erosion can be controlled. This can prevent storm runoff from entering the work area or sediment-laden runoff from leaving the construction site.

Conditions for Use:

- Where the runoff from an exposed site or disturbed slope must be conveyed to an erosion control facility which can safely convey the stormwater. Locate upslope of a construction site to prevent runoff from entering disturbed area.
- When placed horizontally across a disturbed slope, it reduces the amount and velocity of runoff flowing down the slope.
- Locate downslope to collect runoff from a disturbed area and direct it to a sediment basin.

Design Considerations:

- Dike and/or swale and channel must be stabilized with temporary or permanent vegetation or other channel protection during construction.
- Channel requires a positive grade for drainage, steeper grades require channel protection and check dams.
- Review construction for areas where overtopping may occur.
- Can be used at top of new fill before vegetation is established.
- May be used as a permanent diversion channel to carry the runoff.
- Sub-basin tributary area should be one acre or less.
- Design capacity for 10-year, 24-hour storm for temporary facilities, 25-year, 24-hour storm for permanent facilities.

Interceptor dikes shall meet the following criteria:

Top Width	2 feet minimum.
Height	1.5 feet minimum on berm.
Side Slope	2:1 or flatter.
Grade	Depends on topography, however, dike system minimum is 0.5%, maximum is 1%.
Compaction	Minimum of 90 percent ASTM D698 standard proctor.

Horizontal Spacing of Interceptor Dikes:

Average Slope	Slope Percent	Flowpath Length
20H:1V or less	3-5%	300 feet
(10 to 20)H:1V	5-10%	200 feet
(4 to 10)H:1V	10-25%	100 feet
(2 to 4)H:1V	25-50%	50 feet

Stabilization depends on velocity and reach

Slopes <5% Seed and mulch applied within 5 days of dike construction (*see BMP C121, Mulching*).

Slopes 5 - 40% Dependent on runoff velocities and dike materials. Stabilization should be done immediately using either sod or riprap or other measures to avoid erosion.

- The upslope side of the dike shall provide positive drainage to the dike outlet. No erosion shall occur at the outlet. Provide energy dissipation measures as necessary. Sediment-laden runoff must be released through a sediment trapping facility.
- Minimize construction traffic over temporary dikes. Use temporary cross culverts for channel crossing.

Interceptor swales shall meet the following criteria:

Bottom Width 2 feet minimum; the bottom shall be level.
Depth 1-foot minimum.
Side Slope 2:1 or flatter.
Grade Maximum 5 percent, with positive drainage to a suitable outlet (such as a sediment pond).
Stabilization Seed as per BMP C120, Temporary and Permanent Seeding, or BMP C202, Channel Lining, 12 inches thick of riprap pressed into the bank and extending at least 8 inches vertical from the bottom.

- Inspect diversion dikes and interceptor swales once a week and after every rainfall. Immediately remove sediment from the flow area.
- Damage caused by construction traffic or other activity must be repaired before the end of each working day.
- Check outlets and make timely repairs as needed to avoid gully formation. When the area below the temporary diversion dike is permanently stabilized, remove the dike and fill and stabilize the channel to blend with the natural surface.

BMP C201: Grass-Lined Channels

Purpose: To provide a channel with a vegetative lining for conveyance of runoff. See Figure 7.3.9 for typical grass-lined channels.

Conditions of Use: This practice applies to construction sites where concentrated runoff needs to be contained to prevent erosion or flooding.

- When a vegetative lining can provide sufficient stability for the channel cross section and at lower velocities of water (normally dependent on grade). This means that the channel slopes are generally less than 5 percent and space is available for a relatively large cross section.
- Typical uses include roadside ditches, channels at property boundaries, outlets for diversions, and other channels and drainage ditches in low areas.
- Channels that will be vegetated should be installed before major earthwork and hydroseeded with a bonded fiber mulch (BFM). The vegetation should be well established (i.e., 75 percent cover) before water is allowed to flow in the ditch. With channels that will have high flows, erosion control blankets should be installed over the hydroseed. If vegetation cannot be established from seed before water is allowed in the ditch, sod should be installed in the bottom of the ditch in lieu of hydromulch and blankets.

Design and Installation Specifications:

- Locate the channel where it can conform to the topography and other features such as roads.
- Locate them to use natural drainage systems to the greatest extent possible.

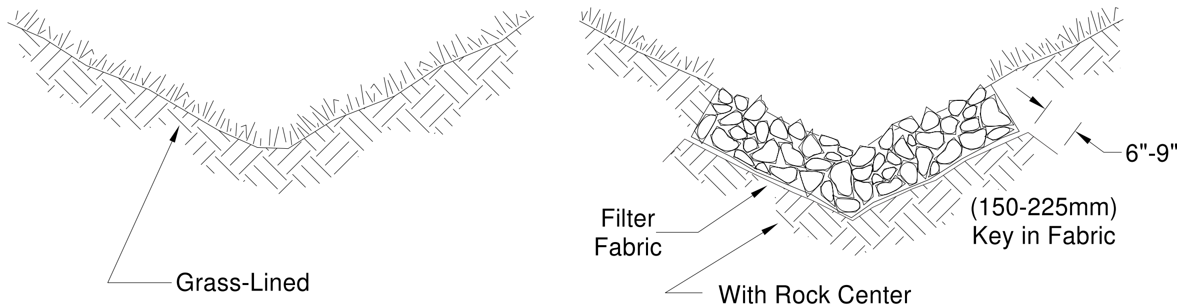
Maintenance Standards:

- During the establishment period, check grass-lined channels after every rainfall.
- Avoid sharp changes in alignment or bends and changes in grade.
- Do not reshape the landscape to fit the drainage channel.
- Design velocities are to be below 5 ft/sec.; however, the design velocity should be based on soil conditions, type of vegetation, and method of establishment.
- An established grass or vegetated lining is required before the channel can be used to convey stormwater, unless stabilized with nets or blankets.
- If design velocity of a channel to be vegetated by seeding exceeds 2 ft/sec, a temporary channel liner is required. Geotextile or special mulch protection such as fiberglass roving or straw and netting provide stability until the vegetation is fully established. See Figure 4.10.
- Check dams shall be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4

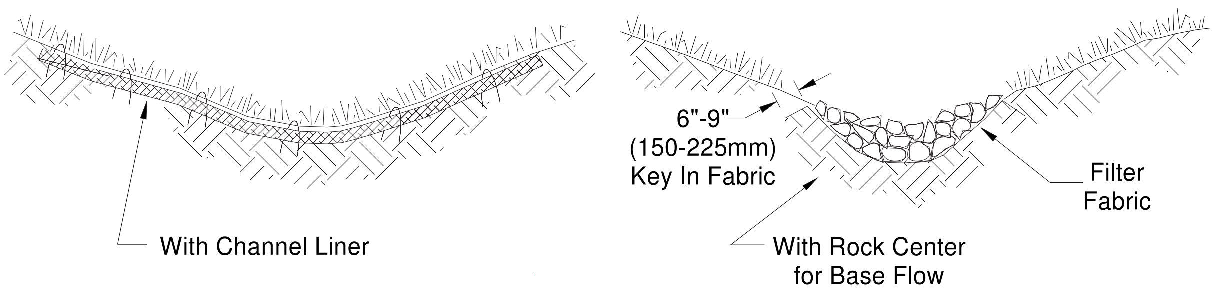
percent. The area beneath the check dams shall be seeded and mulched immediately after dam removal.

- If vegetation is established by sodding, the permissible velocity for established vegetation may be used and no temporary liner is needed.
- Do not subject grass-lined channel to sedimentation from disturbed areas. Use sediment-trapping BMPs upstream of the channel.
- V-shaped grass channels generally apply where the quantity of water is small, such as in short reaches along roadsides. The V-shaped cross section is least desirable because it is difficult to stabilize the bottom where velocities may be high.
- Trapezoidal grass channels are used where runoff volumes are large and slope is low so that velocities are nonerosive to vegetated linings. (Note: it is difficult to construct small parabolic shaped channels.)
- Subsurface drainage, or riprap channel bottoms, may be necessary on sites that are subject to prolonged wet conditions due to long duration flows or a high water table.
- Provide outlet protection at culvert ends and at channel intersections.
- Grass channels, at a minimum, should carry peak runoff for temporary construction drainage facilities from the 10-year, 24-hour storm without eroding. Where flood hazard exists, increase the capacity according to the potential damage.
- Grassed channel side slopes generally are constructed 3:1 or flatter to aid in the establishment of vegetation and for maintenance.
- Construct channels a minimum of 0.2 foot larger around the periphery to allow for soil bulking during seedbed preparations and sod buildup.
- After grass is established, periodically check the channel; check it after every heavy rainfall event. Immediately make repairs.
- It is particularly important to check the channel outlet and all road crossings for bank stability and evidence of piping or scour holes.
- Remove all significant sediment accumulations to maintain the designed carrying capacity. Keep the grass in a healthy, vigorous condition at all times, since it is the primary erosion protection for the channel.

Typical V-Shaped Channel Cross-section



Typical Parabolic Channel Cross-Section



Typical Trapezoidal Channel Cross-Section

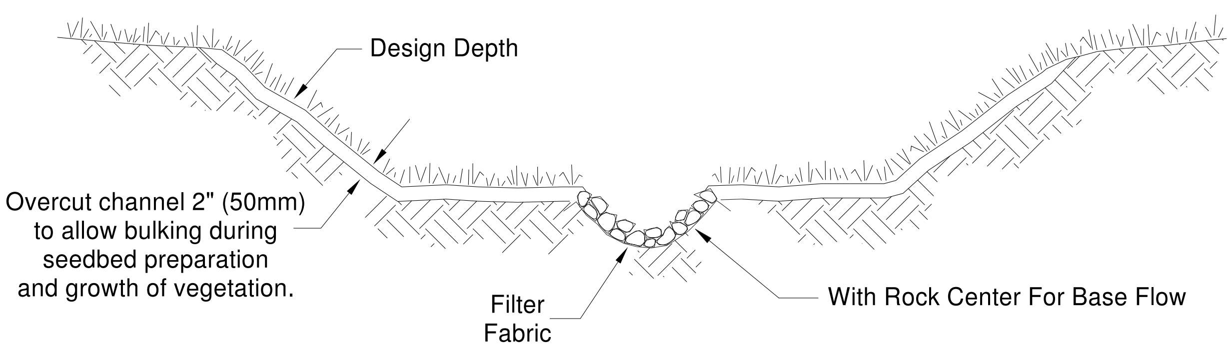
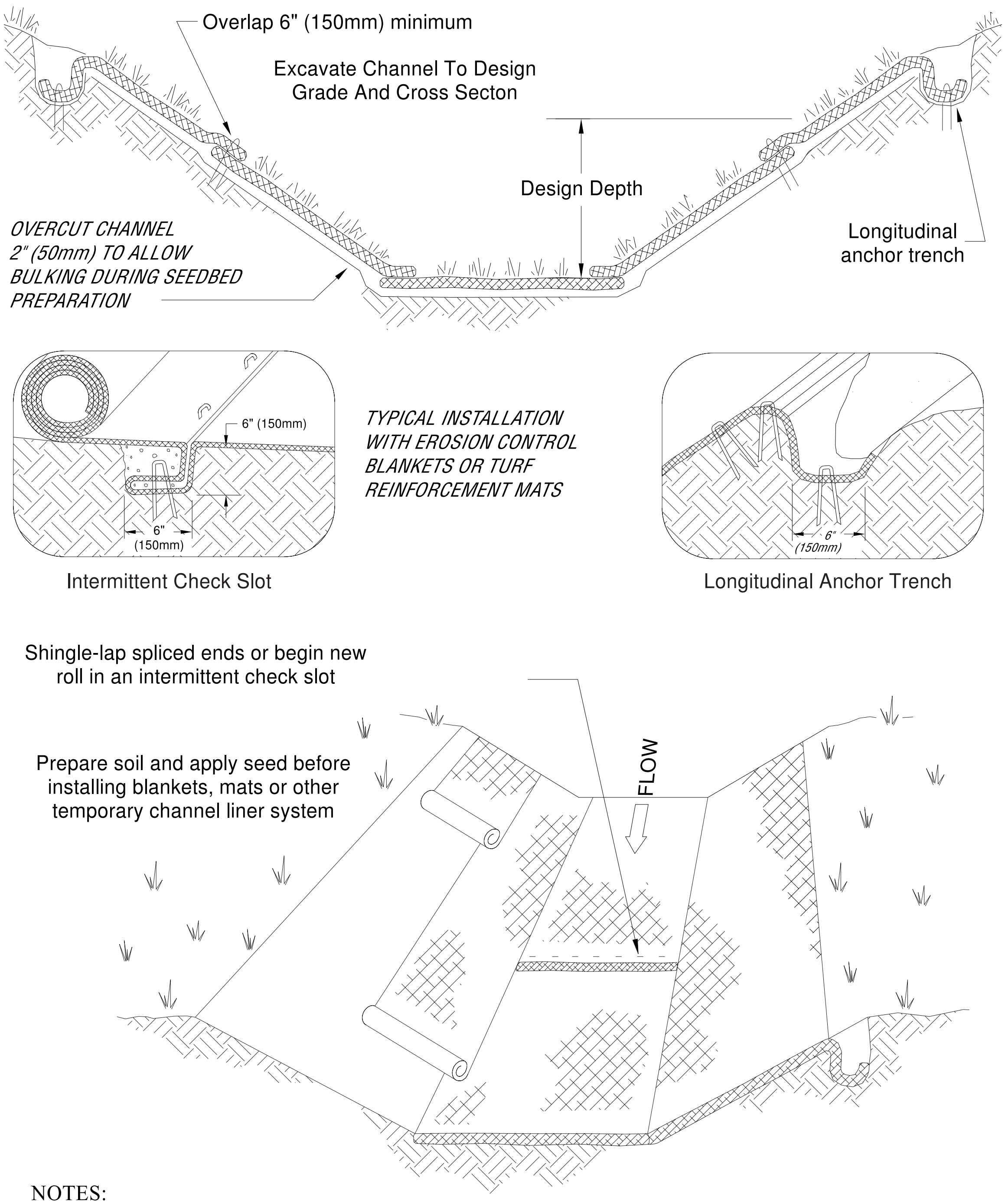


Figure 7.3.9 – Typical Grass-Lined Channels



NOTES:
1. Design velocities exceeding 2 ft/sec (0.5m/sec) require temporary blankets, mats or similar liners to protect seed and soil until vegetation becomes established.
2. Grass-lined channels with design velocities exceeding 6 ft/sec (2m/sec) should include turf reinforcement mats.

Figure 7.3.10 - Temporary Channel Liners

BMP C202: Channel Lining

Purpose: To protect erodible channels by providing a channel liner using either blankets or riprap.

Conditions of Use:

- When natural soils or vegetated stabilized soils in a channel are not adequate to prevent channel erosion.
- When a permanent ditch or pipe system is to be installed and a temporary measure is needed.
- In almost all cases, synthetic and organic coconut blankets are more effective than riprap for protecting channels from erosion. Blankets can be used with and without vegetation. Blanketed channels can be designed to handle any expected flow and longevity requirement. Some synthetic blankets have a predicted life span of 50 years or more, even in sunlight.
- Other reasons why blankets are better than rock include the availability of blankets over rock. In many areas of the state, rock is not easily obtainable or is very expensive to haul to a site. Blankets can be delivered anywhere. Rock requires the use of dump trucks to haul and heavy equipment to place. Blankets usually only require laborers with hand tools, and sometimes a backhoe.
- The Federal Highway Administration recommends not using flexible liners whenever the slope exceeds 10 percent or the shear stress exceeds 8 lbs/ft^2.

Design and Installation Specifications:

- See BMP C122 for information on blankets.
- Since riprap is used where erosion potential is high, construction must be sequenced so that the riprap is put in place with the minimum possible delay.
- Disturbance of areas where riprap is to be placed should be undertaken only when final preparation and placement of the riprap can follow immediately behind the initial disturbance. Where riprap is used for outlet protection, the riprap should be placed before or in conjunction with the construction of the pipe or channel so that it is in place when the pipe or channel begins to operate.
- The designer, after determining the riprap size that will be stable under the flow conditions, shall consider that size to be a minimum size and then, based on riprap gradations actually available in the area, select the size or sizes that equal or exceed the minimum size. The possibility of drainage structure damage by children shall be considered in selecting a riprap size, especially if there is nearby water or a gully in which to toss the stones.
- Stone for riprap shall consist of field stone or quarry stone of approximately rectangular shape. The stone shall be hard and angular and of such quality that it will not disintegrate on exposure to water or weathering and it shall be suitable in all respects for the purpose intended.

- Rubble concrete may be used provided it has a density of at least 150 pounds per cubic foot, and otherwise meets the requirement of this standard and specification.
- A lining of engineering filter fabric (geotextile) shall be placed between the riprap and the underlying soil surface to prevent soil movement into or through the riprap. The geotextile should be keyed in at the top of the bank.
- Filter fabric shall not be used on slopes greater than 1-1/2:1 as slippage may occur. It should be used in conjunction with a layer of coarse aggregate (granular filter blanket) when the riprap to be placed is 12 inches and larger.

BMP C203: Water Bars

Purpose: A small ditch or ridge of material is constructed diagonally across a road or right-of-way to divert stormwater runoff from the road surface, wheel tracks, or a shallow road ditch.

Conditions of Use:

- Clearing right-of-way and construction of access for power lines, pipelines, and other similar installations often require long narrow right-of-ways over sloping terrain. Disturbance and compaction promotes gully formation in these cleared strips by increasing the volume and velocity of runoff. Gully formation may be especially severe in tire tracks and ruts. To prevent gullying, runoff can often be diverted across the width of the right-of-way to undisturbed areas by using small predesigned diversions.
- Give special consideration to each individual outlet area, as well as to the cumulative effect of added diversions. Use gravel to stabilize the diversion where significant vehicular traffic is anticipated.

Design and Installation Specifications: Height: 8-inch minimum measured from the channel bottom to the ridge top.

- Side slope of channel: 2:1 maximum; 3:1 or flatter when vehicles will cross.
- Base width of ridge: 6-inch minimum.
- Locate them to use natural drainage systems and to discharge into well vegetated stable areas.

Guideline for Spacing:

Slope %	Spacing (ft)
< 5	125
5 - 10	100
10 - 20	75
20 - 35	50
> 35	Use rock lined ditch

- Grade of water bar and angle: Select angle that results in ditch slope less than 2 percent.
- Install as soon as the clearing and grading is complete. Reconstruct when construction is complete on a section when utilities are being installed.
- Compact the ridge when installed.
- Stabilize, seed and mulch the portions that are not subject to traffic. Gravel the areas crossed by vehicles.

Maintenance Standards:

- Periodically inspect right-of-way diversions for wear and after every heavy rainfall for erosion damage.
- Immediately remove sediment from the flow area and repair the dike.

- Check outlet areas and make timely repairs as needed.
- When permanent road drainage is established and the area above the temporary right-of-way diversion is permanently stabilized, remove the dike and fill the channel to blend with the natural ground, and appropriately stabilize the disturbed area.

BMP C204: Pipe Slope Drains

Purpose: To use a pipe to convey stormwater anytime water needs to be diverted away from or over bare soil to prevent gullies, channel erosion, and saturation of slide-prone soils.

Conditions of Use: Pipe slope drains should be used when a temporary or permanent stormwater conveyance is needed to move the water down a steep slope to avoid erosion (Figure 7.3.11).

On highway projects, they should be used at bridge ends to collect runoff and pipe it to the base of the fill slopes along bridge approaches. These can be designed into a project and included as bid items. Another use on road projects is to collect runoff from pavement and pipe it away from side slopes. These are useful because there is generally a time lag between having the first lift of asphalt installed and the curbs, gutters, and permanent drainage installed. Used in conjunction with sand bags, or other temporary diversion devices, these will prevent massive amounts of sediment from leaving a project.

Water can be collected, channeled with sand bags, Triangular Silt Dikes, berms, or other material, and piped to temporary sediment ponds.

Pipe slope drains can be:

- Connected to new catch basins and used temporarily until all permanent piping is installed;
- Used to drain water collected from aquifers exposed on cut slopes and take it to the base of the slope;
- Used to collect clean runoff from plastic sheeting and direct it away from exposed soil;
- Installed in conjunction with silt fence to drain collected water to a controlled area;
- Used to divert small seasonal streams away from construction. They have been used successfully on culvert replacement and extension jobs. Large flex pipe can be used on larger streams during culvert removal, repair, or replacement; and,
- Connected to existing down spouts and roof drains and used to divert water away from work areas during building renovation, demolition, and construction projects.
- There are now several commercially available collectors that are attached to the pipe inlet and help prevent erosion at the inlet.

Design and Installation Specifications: Size the pipe to convey the flow. The capacity for temporary drains shall be sufficient to handle the peak flow from a 10-year, 24-hour storm event. Permanent pipe slope drains shall be sized for the 25-year, 24-hour peak flow.

- Use care in clearing vegetated slopes for installation.

- Re-establish cover immediately on areas disturbed by installation.
- Use temporary drains on new cut or fill slopes.
- Use diversion dikes or swales to collect water at the top of the slope.
- Ensure that the entrance area is stable and large enough to direct flow into the pipe.
- Piping of water through the berm at the entrance area is a common failure mode.
- The entrance shall consist of a standard flared end section for culverts 12 inches and larger with a minimum 6-inch metal toe plate to prevent runoff from undercutting the pipe inlet. The slope of the entrance shall be at least 3 percent. Sand bags may also be used at pipe entrances as a temporary measure.
- The soil around and under the pipe and entrance section shall be thoroughly compacted to prevent undercutting.
- The flared inlet section shall be securely connected to the slope drain and have watertight connecting bands.
- Slope drain sections shall be securely fastened together, fused or have gasketed watertight fittings, and shall be securely anchored into the soil.
- Thrust blocks should be installed anytime 90 degree bends are utilized. Depending on size of pipe and flow, these can be constructed with sand bags, straw bales staked in place, "t" posts and wire, or ecology blocks.
- Pipe needs to be secured along its full length to prevent movement. This can be done with steel "t" posts and wire. A post is installed on each side of the pipe and the pipe is wired to them. This should be done every 10-20 feet of pipe length or so, depending on the size of the pipe and quantity of water to be diverted.
- Interceptor dikes shall be used to direct runoff into a slope drain. The height of the dike shall be at least 1 foot higher at all points than the top of the inlet pipe.
- The area below the outlet must be stabilized with a riprap apron (see BMP C209 Outlet Protection, for the appropriate outlet material).
- If the pipe slope drain is conveying sediment-laden water, direct all flows into the sediment trapping facility.
- Materials specifications for any permanent piped system shall be set by the local government.

Maintenance Standards: Check inlet and outlet points regularly, especially after storms.

The inlet should be free of undercutting, and no water should be going around the point of entry. If there are problems, the headwall should be reinforced with compacted earth or sand bags.

- The outlet point should be free of erosion and installed with appropriate outlet protection.
- For permanent installations, inspect pipe periodically for vandalism and physical distress such as slides and wind-throw.
- Normally the pipe slope is so steep that clogging is not a problem with smooth wall pipe, however, debris may become lodged in the pipe.

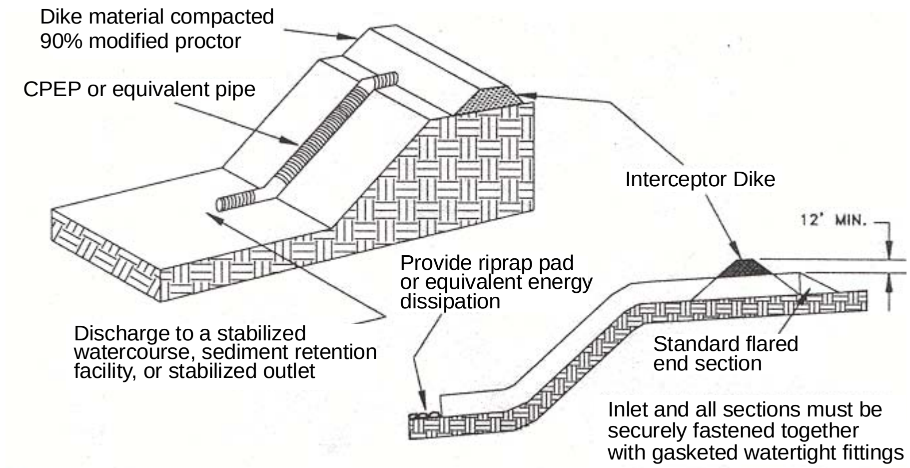


Figure 7.3.11 - Pipe Slope Drain

BMP C205: Subsurface Drains

Purpose: To intercept, collect, and convey ground water to a satisfactory outlet, using a perforated pipe or conduit below the ground surface. Subsurface drains are also known as “french drains.” The perforated pipe provides a dewatering mechanism to drain excessively wet soils, provide a stable base for construction, improve stability of structures with shallow foundations, or to reduce hydrostatic pressure to improve slope stability.

Conditions of Use: Use when excessive water must be removed from the soil. The soil permeability, depth to water table and impervious layers are all factors which may govern the use of subsurface drains.

Design and Installation Specifications:

- **Relief drains** are used either to lower the water table in large, relatively flat areas, improve the growth of vegetation, or to remove surface water.

  They are installed along a slope and drain in the direction of the slope.

  They can be installed in a grid pattern, a herringbone pattern, or a random pattern.

- **Interceptor drains a**re used to remove excess ground water from a slope, stabilize steep slopes, and lower the water table immediately below a slope to prevent the soil from becoming saturated.

  They are installed perpendicular to a slope and drain to the side of the slope.

  They usually consist of a single pipe or series of single pipes instead of a patterned layout.

- **Depth and spacing of interceptor drains** - The depth of an interceptor drain is determined primarily by the depth to which the water table is to be lowered or the depth to a confining layer. For practical reasons, the maximum depth is usually limited to 6 feet, with a minimum cover of 2 feet to protect the conduit.

- The soil should have depth and sufficient permeability to permit installation of an effective drainage system at a depth of 2 to 6 feet.

- An adequate outlet for the drainage system must be available either by gravity or by pumping.

- The quantity and quality of discharge needs to be accounted for in the receiving stream (additional detention may be required).

- This standard does not apply to subsurface drains for building foundations or deep excavations.

- The capacity of an interceptor drain is determined by calculating the maximum rate of ground water flow to be intercepted. Therefore, it is good practice to make complete subsurface investigations, including hydraulic conductivity of the soil, before designing a subsurface drainage system.

- **Size of drain** - Size subsurface drains to carry the required capacity without pressure flow. Minimum diameter for a subsurface drain is 4 inches.

- The minimum velocity required to prevent silting is 1.4 ft./sec. The line shall be graded to achieve this velocity at a minimum. The maximum allowable velocity using a sand-gravel filter or envelope is 9 ft/sec.
- Filter material and fabric shall be used around all drains for proper bedding and filtration of fine materials. Envelopes and filters should surround the drain to a minimum of 3-inch thickness.
- The outlet of the subsurface drain shall empty into a sediment pond through a catch basin. If free of sediment, it can then empty into a receiving channel, swale, or stable vegetated area adequately protected from erosion and undermining.
- The trench shall be constructed on a continuous grade with no reverse grades or low spots.
- Soft or yielding soils under the drain shall be stabilized with gravel or other suitable material.
- Backfilling shall be done immediately after placement of the pipe. No sections of pipe shall remain uncovered overnight or during a rainstorm. Backfill material shall be placed in the trench in such a manner that the drain pipe is not displaced or damaged.
- Do not install permanent drains near trees to avoid the tree roots that tend to clog the line. Use solid pipe with watertight connections where it is necessary to pass a subsurface drainage system through a stand of trees.
- Outlet -Ensure that the outlet of a drain empties into a channel or other watercourse above the normal water level.
- Secure an animal guard to the outlet end of the pipe to keep out rodents.
- Use outlet pipe of corrugated metal, cast iron, or heavy-duty plastic without perforations and at least 10 feet long. Do not use an envelope or filter material around the outlet pipe, and bury at least two-thirds of the pipe length.
- When outlet velocities exceed those allowable for the receiving stream, outlet protection must be provided.

Maintenance Standards: Subsurface drains shall be checked periodically to ensure that they are free-flowing and not clogged with sediment or roots.

- The outlet shall be kept clean and free of debris.
- Surface inlets shall be kept open and free of sediment and other debris.
- Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain or remove the trees as a last resort. Drain placement should be planned to minimize this problem.
- Where drains are crossed by heavy vehicles, the line shall be checked to ensure that it is not crushed.

BMP C206: Level Spreader

Purpose: To provide a temporary outlet for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope. To convert concentrated runoff to sheet flow and release it onto areas stabilized by existing vegetation or an engineered filter strip.

Conditions of Use: Used when a concentrated flow of water needs to be dispersed over a large area with existing stable vegetation.

Items to consider are:

- What is the risk of erosion or damage if the flow may become concentrated?
- Is an easement required if discharged to adjoining property?
- Most of the flow should be as ground water and not as surface flow.
- Is there an unstable area downstream that cannot accept additional ground water?
- Use only where the slopes are gentle, the water volume is relatively low, and the soil will adsorb most of the low flow events.

Design and Installation Specifications: Use above undisturbed areas that are stabilized by existing vegetation.

If the level spreader has any low points, flow will concentrate, create channels and may cause erosion.

- Discharge area below the outlet must be uniform with a slope of less than 5H:1V.
- Outlet to be constructed level in a stable, undisturbed soil profile (not on fill).
- The runoff shall not re-concentrate after release unless intercepted by another downstream measure.
- The grade of the channel for the last 20 feet of the dike or interceptor entering the level spreader shall be less than or equal to 1 percent. The grade of the level spreader shall be 0 percent to ensure uniform spreading of storm runoff.
- A 6-inch high gravel berm placed across the level lip shall consist of washed crushed rock, 2- to 4-inch or ¾-inch to 1½-inch size.
- The spreader length shall be determined by estimating the peak flow expected from the 10-year, 24-hour design storm. The length of the spreader shall be a minimum of 15 feet for 0.1 cfs and shall be 10 feet for each 0.1 cfs there after to a maximum of 0.5 cfs per spreader. Use multiple spreaders for higher flows.
- The width of the spreader should be at least 6 feet.
- The depth of the spreader as measured from the lip should be at least 6 inches and it should be uniform across the entire length.
- Level spreaders shall be setback from the property line unless there is an easement for flow.

- Level spreaders, when installed every so often in grassy swales, keep the flows from concentrating. Materials that can be used include sand bags, lumber, logs, concrete, and pipe. To function properly, the material needs to be installed level and on contour. Figures 7.3.12 and 7.3.13 provide a cross-section and a detail of a level spreader.

Maintenance Standards: The spreader should be inspected after every runoff event to ensure that it is functioning correctly.

- The contractor should avoid the placement of any material on the structure and should prevent construction traffic from crossing over the structure.
- If the spreader is damaged by construction traffic, it shall be immediately repaired.

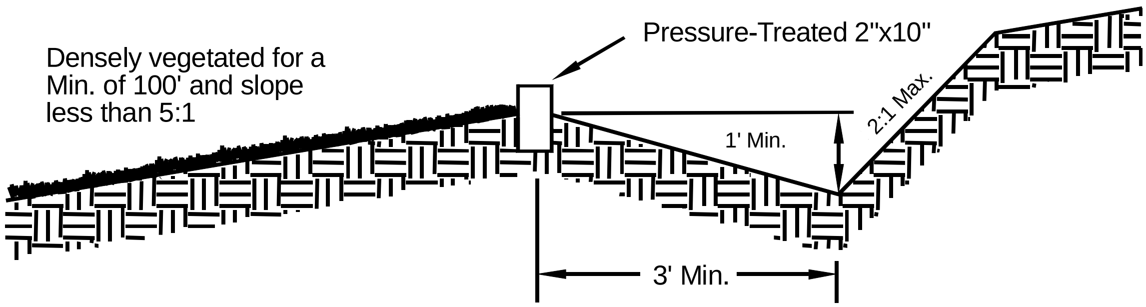


Figure 7.3.12 - Level-spreader Profile

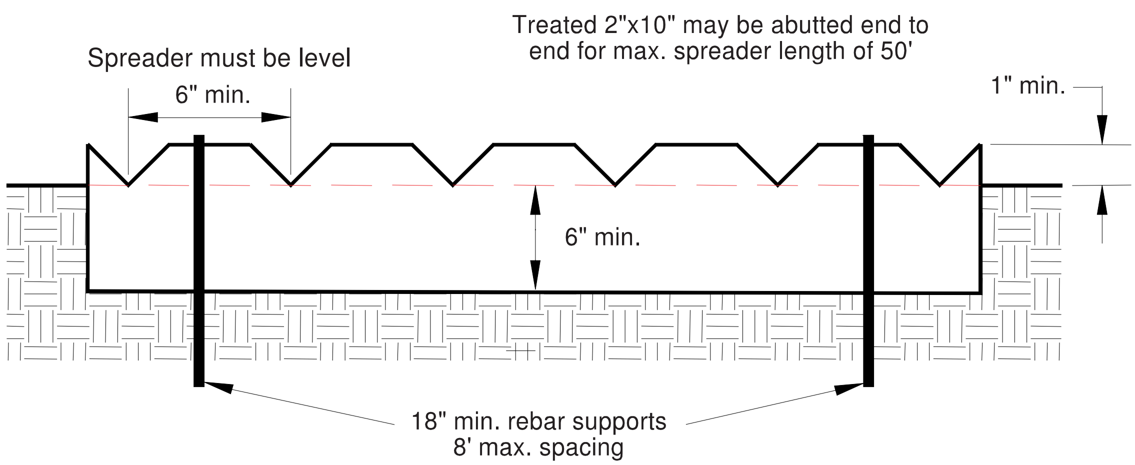


Figure 7.3.13 - Level Spreader Elevation

BMP C207: Check Dams

Purpose: Construction of small dams across a swale or ditch reduces the velocity of concentrated flow and dissipates energy at the check dam.

Conditions of Use: Where temporary channels or permanent channels are not yet vegetated, channel lining is infeasible, and velocity checks are required.

- Check dams may not be placed in streams unless approved by the State Department of Fish and Wildlife. Check dams may not be placed in wetlands without approval from a permitting agency.
- Check dams shall not be placed below the expected backwater from any salmonid bearing water between October 1 and May 31 to ensure that there is no loss of high flow refuge habitat for overwintering juvenile salmonids and emergent salmonid fry.

Design and Installation Specifications: Whatever material is used, the dam should form a triangle when viewed from the side. This prevents undercutting as water flows over the face of the dam rather than falling directly onto the ditch bottom.

- Check dams in association with sumps work more effectively at slowing flow and retaining sediment than just a check dam alone. A deep sump should be provided immediately upstream of the check dam.
- In some cases, if carefully located and designed, check dams can remain as permanent installations with very minor regrading. They may be left as either spillways, in which case accumulated sediment would be graded and seeded, or as check dams to prevent further sediment from leaving the site.
- Check dams can be constructed of either rock or pea-gravel filled bags. Numerous new products are also available for this purpose. They tend to be re-usable, quick and easy to install, effective, and cost efficient.
- Check dams should be placed perpendicular to the flow of water.
- The maximum spacing between the dams shall be such that the toe of the upstream dam is at the same elevation as the top of the downstream dam.
- Keep the maximum height at 2 feet at the center of the dam.
- Keep the center of the check dam at least 12 inches lower than the outer edges at natural ground elevation.
- Keep the side slopes of the check dam at 2:1 or flatter.
- Key the stone into the ditch banks and extend it beyond the abutments a minimum of 18 inches to avoid washouts from overflow around the dam.
- Use filter fabric foundation under a rock or sand bag check dam. If a blanket ditch liner is used, this is not necessary. A piece of organic or synthetic blanket cut to fit will also work for this purpose.

- Rock check dams shall be constructed of appropriately sized rock. The rock must be placed by hand or by mechanical means (no dumping of rock to form dam) to achieve complete coverage of the ditch or swale and to ensure that the center of the dam is lower than the edges. The rock used must be large enough to stay in place given the expected design flow through the channel.
- In the case of grass-lined ditches and swales, all check dams and accumulated sediment shall be removed when the grass has matured sufficiently to protect the ditch or swale - unless the slope of the swale is greater than 4 percent. The area beneath the check dams shall be seeded and mulched immediately after dam removal.
- Ensure that channel appurtenances, such as culvert entrances below check dams, are not subject to damage or blockage from displaced stones. Figure 7.3.14 depicts a typical rock check dam.

Maintenance Standards: Check dams shall be monitored for performance and sediment accumulation during and after each runoff producing rainfall. Sediment shall be removed when it reaches one half the sump depth.

- Anticipate submergence and deposition above the check dam and erosion from high flows around the edges of the dam.
- If significant erosion occurs between dams, install a protective riprap liner in that portion of the channel.

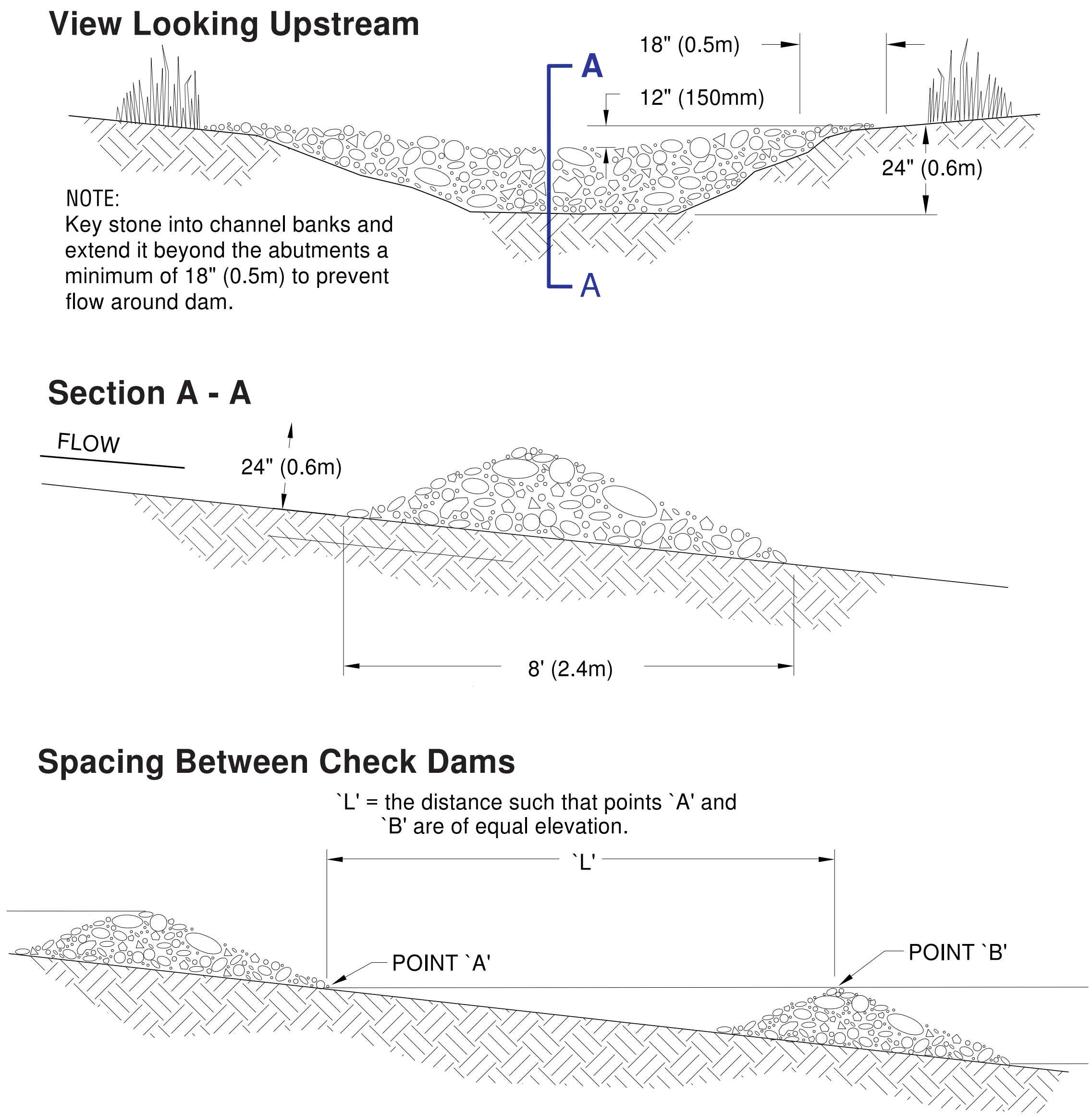


Figure 7.3.14 - Check Dams

NOT TO SCALE

BMP C208: Triangular Silt Dike (Geotextile-Encased Check Dam)

Purpose: Triangular silt dikes may be used as check dams, for perimeter protection, for temporary soil stockpile protection, for drop inlet protection, or as a temporary interceptor dike.

Conditions of Use:

- May be used in place of straw bales for temporary check dams in ditches of any dimension.
- May be used on soil or pavement with adhesive or staples.
- TSDs have been used to build temporary:
    - sediment ponds;
    - diversion ditches;
    - concrete wash out facilities;
    - curbing;
    - water bars;
    - level spreaders; and,
    - berms.

Design and Installation Specifications: Made of urethane foam sewn into a woven geosynthetic fabric.

It is triangular, 10 inches to 14 inches high in the center, with a 20-inch to 28-inch base. A 2–foot apron extends beyond both sides of the triangle along its standard section of 7 feet. A sleeve at one end allows attachment of additional sections as needed.

- Install with ends curved up to prevent water from flowing around the ends.
- The fabric flaps and check dam units are attached to the ground with wire staples. Wire staples should be No. 11 gauge wire and should be 200 mm to 300 mm in length.
- When multiple units are installed, the sleeve of fabric at the end of the unit shall overlap the abutting unit and be stapled.
- Check dams should be located and installed as soon as construction will allow.
- Check dams should be placed perpendicular to the flow of water.
- When used as check dams, the leading edge must be secured with rocks, sandbags, or a small key slot and staples.
- In the case of grass-lined ditches and swales, check dams and accumulated sediment shall be removed when the grass has matured sufficiently to protect the ditch or swale unless the slope of the swale is greater than 4 percent. The

area beneath the check dams shall be seeded and mulched immediately after dam removal.

Maintenance Standards: Triangular silt dams shall be monitored for performance and sediment accumulation during and after each runoff producing rainfall. Sediment shall be removed when it reaches one half the height of the dam.

- Anticipate submergence and deposition above the triangular silt dam and erosion from high flows around the edges of the dam. Immediately repair any damage or any undercutting of the dam.

BMP C209: Outlet Protection

Purpose: Outlet protection prevents scour at conveyance outlets and minimizes the potential for downstream erosion by reducing the velocity of concentrated stormwater flows.

Conditions of Use: Outlet protection is required at the outlets of all ponds, pipes, ditches, or other conveyances, and where runoff is conveyed to a natural or manmade drainage feature such as a stream, wetland, lake, or ditch.

Design and Installation Specifications: The receiving channel at the outlet of a culvert shall be protected from erosion by rock lining a minimum of 6 feet downstream and extending up the channel sides a minimum of 1–foot above the maximum tailwater elevation or 1-foot above the crown, whichever is higher. For large pipes (more than 18 inches in diameter), the outlet protection lining of the channel is lengthened to four times the diameter of the culvert.

- Standard wingwalls, and tapered outlets and paved channels should also be considered when appropriate for permanent culvert outlet protection. (See WSDOT Hydraulic Manual, available through WSDOT Engineering Publications).
- Organic or synthetic erosion blankets, with or without vegetation, are usually more effective than rock, cheaper, and easier to install. Materials can be chosen using manufacturer product specifications. ASTM test results are available for most products and the designer can choose the correct material for the expected flow.
- With low flows, vegetation (including sod) can be effective.
- The following guidelines shall be used for riprap outlet protection:
- If the discharge velocity at the outlet is less than 5 fps (pipe slope less than 1 percent), use 2-inch to 8-inch riprap. Minimum thickness is 1-foot.
- For 5 to 10 fps discharge velocity at the outlet (pipe slope less than 3 percent), use 24-inch to 4-foot riprap. Minimum thickness is 2 feet.
- For outlets at the base of steep slope pipes (pipe slope greater than 10 percent), an engineered energy dissipator shall be used.
- Filter fabric or erosion control blankets should always be used under riprap to prevent scour and channel erosion.
- New pipe outfalls can provide an opportunity for low-cost fish habitat improvements. For example, an alcove of low-velocity water can be created by constructing the pipe outfall and associated energy dissipator back from the stream edge and digging a channel, over-widened to the upstream side, from the outfall. Overwintering juvenile and migrating adult salmonids may use the alcove as shelter during high flows. Bank stabilization, bioengineering, and habitat features may be required for disturbed areas. See Chapter 6 for more information on outfall system design.

Maintenance Standards:

- Inspect and repair as needed.
- Add rock as needed to maintain the intended function.
- Clean energy dissipator if sediment builds up.

BMP C220: Storm Drain Inlet Protection

Purpose: To prevent coarse sediment from entering drainage systems prior to permanent stabilization of the disturbed area.

Conditions of Use: Where storm drain inlets are to be made operational before permanent stabilization of the disturbed drainage area. Protection should be provided for all storm drain inlets downslope and within 500 feet of a disturbed or construction area, unless the runoff that enters the catch basin will be conveyed to a sediment pond or trap. Inlet protection may be used anywhere to protect the drainage system. It is likely that the drainage system will still require cleaning.

Table 7.3.9 lists several options for inlet protection. All of the methods for storm drain inlet protection are prone to plugging and require a high frequency of maintenance. Drainage areas should be limited to 1 acre or less. Emergency overflows may be required where stormwater ponding would cause a hazard. If an emergency overflow is provided, additional end-of-pipe treatment may be required.

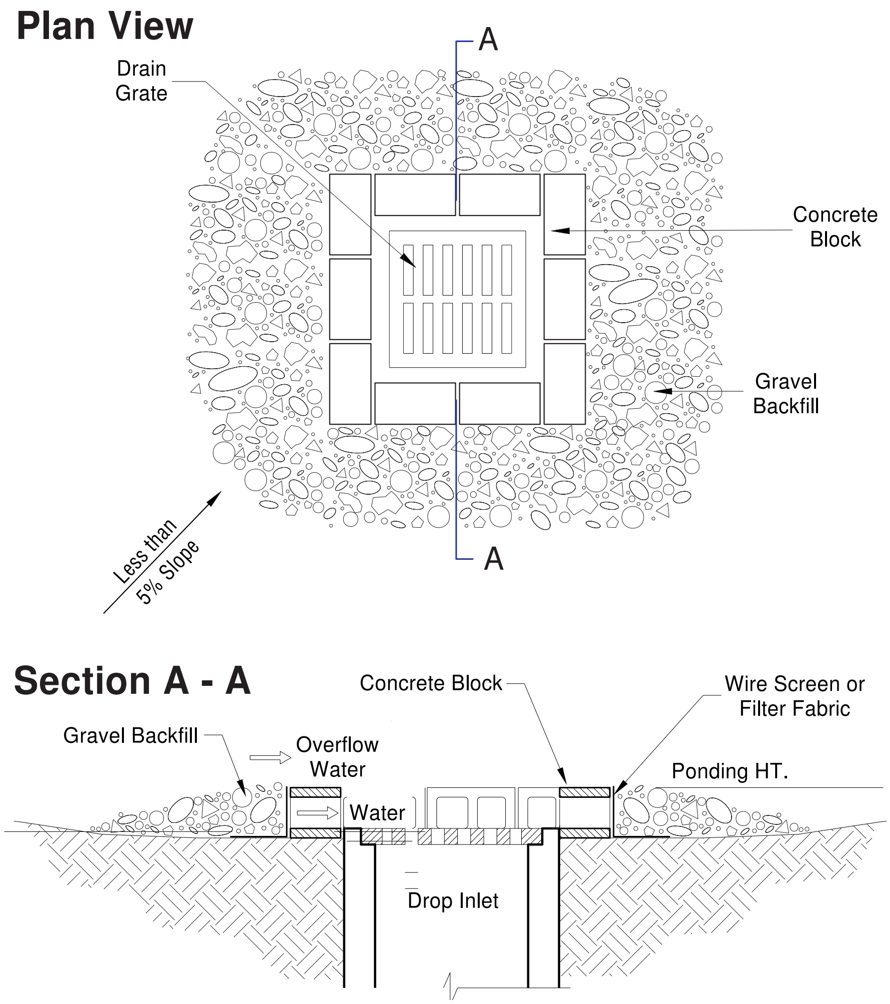
Design and Installation Specifications: Excavated Drop Inlet Protection - An excavated impoundment around the storm drain. Sediment settles out of the stormwater prior to entering the storm drain.

- Depth 1-2 ft as measured from the crest of the inlet structure.
- Side Slopes of excavation no steeper than 2:1.
- Minimum volume of excavation 35 cubic yards.
- Shape basin to fit site with longest dimension oriented toward the longest inflow area.
- Install provisions for draining to prevent standing water problems.
- Clear the area of all debris.
- Grade the approach to the inlet uniformly.
- Drill weep holes into the side of the inlet.
- Protect weep holes with screen wire and washed aggregate.
- Seal weep holes when removing structure and stabilizing area.
- It may be necessary to build a temporary dike to the down slope side of the structure to prevent bypass flow.
- Block and Gravel Filter - A barrier formed around the storm drain inlet with standard concrete blocks and gravel. See Figure 4.15.
- Height 1 to 2 feet above inlet.
- Recess the first row 2 inches into the ground for stability.
- Support subsequent courses by placing a 2x4 through the block opening.

- Do not use mortar.
- Lay some blocks in the bottom row on their side for dewatering the pool.
- Place hardware cloth or comparable wire mesh with ½-inch openings over all block openings.
- Place gravel just below the top of blocks on slopes of 2:1 or flatter.
- An alternative design is a gravel donut.
- Inlet slope of 3:1.
- Outlet slope of 2:1.
- 1-foot wide level stone area between the structure and the inlet.
- Inlet slope stones 3 inches in diameter or larger.
- Outlet slope use gravel ½- to ¾-inch at a minimum thickness of 1-foot.

Table 7.3.9 Storm Drain Inlet Protection

Type of Inlet Protection	Emergency Overflow	Applicable for Paved/ Earthen Surfaces	Conditions of Use
Drop Inlet Protection			
Excavated drop inlet protection	Yes, temporary flooding will occur	Earthen	Applicable for heavy flows. Easy to maintain. Large area Requirement: 30' X 30'/acre
Block and gravel drop inlet protection	Yes	Paved or Earthen	Applicable for heavy concentrated flows. Will not pond.
Gravel and wire drop inlet protection	No		Applicable for heavy concentrated flows. Will pond. Can withstand traffic.
Catch basin filters	Yes	Paved or Earthen	Frequent maintenance required.
Curb Inlet Protection			
Curb inlet protection with a wooden weir	Small capacity overflow	Paved	Used for sturdy, more compact installation.
Block and gravel curb inlet protection	Yes	Paved	Sturdy, but limited filtration.
Culvert Inlet Protection			
Culvert inlet sediment trap			18 month expected life.



Notes:
1. Drop inlet sediment barriers are to be used for small, nearly level drainage areas. (less than 5%)
2. Excavate a basin of sufficient size adjacent to the drop inlet.
3. The top of the structure (ponding height) must be well below the ground elevation downslope to prevent runoff from bypassing the inlet. A temporary dike may be necessary on the downslope side of the structure.

Figure 7.3.15 – Block and Gravel Filter

Gravel and Wire Mesh Filter - A gravel barrier placed over the top of the inlet. This structure does not provide an overflow.

- Hardware cloth or comparable wire mesh with ½-inch openings.
- Coarse aggregate.
- Height 1-foot or more, 18 inches wider than inlet on all sides.
- Place wire mesh over the drop inlet so that the wire extends a minimum of 1-foot beyond each side of the inlet structure.
- If more than one strip of mesh is necessary, overlap the strips.
- Place coarse aggregate over the wire mesh.
- The depth of the gravel should be at least 12 inches over the entire inlet opening and extend at least 18 inches on all sides.

Catchbasin Filters - Inserts should be designed by the manufacturer for use at construction sites. The limited sediment storage capacity increases the amount of inspection and maintenance required, which may be daily for heavy sediment loads. The maintenance requirements can be reduced by combining a catchbasin filter with another type of inlet protection. This type of inlet protection provides flow bypass without overflow and therefore may be a better method for inlets located along active rights-of-way.

- 5 cubic feet of storage.
- Dewatering provisions.
- High-flow bypass that will not clog under normal use at a construction site.
- The catchbasin filter is inserted in the catchbasin just below the grating.

Curb Inlet Protection with Wooden Weir – Barrier formed around a curb inlet with a wooden frame and gravel.

- Wire mesh with ½-inch openings.
- Extra strength filter cloth.
- Construct a frame.
- Attach the wire and filter fabric to the frame.
- Pile coarse washed aggregate against wire/fabric.
- Place weight on frame anchors.

Block and Gravel Curb Inlet Protection – Barrier formed around an inlet with concrete blocks and gravel. See Figure 7.3.16.

- Wire mesh with ½-inch openings.
- Place two concrete blocks on their sides abutting the curb at either side of the inlet opening. These are spacer blocks.
- Place a 2x4 stud through the outer holes of each spacer block to align the front blocks.

- Place blocks on their sides across the front of the inlet and abutting the spacer blocks.
- Place wire mesh over the outside vertical face.
- Pile coarse aggregate against the wire to the top of the barrier.

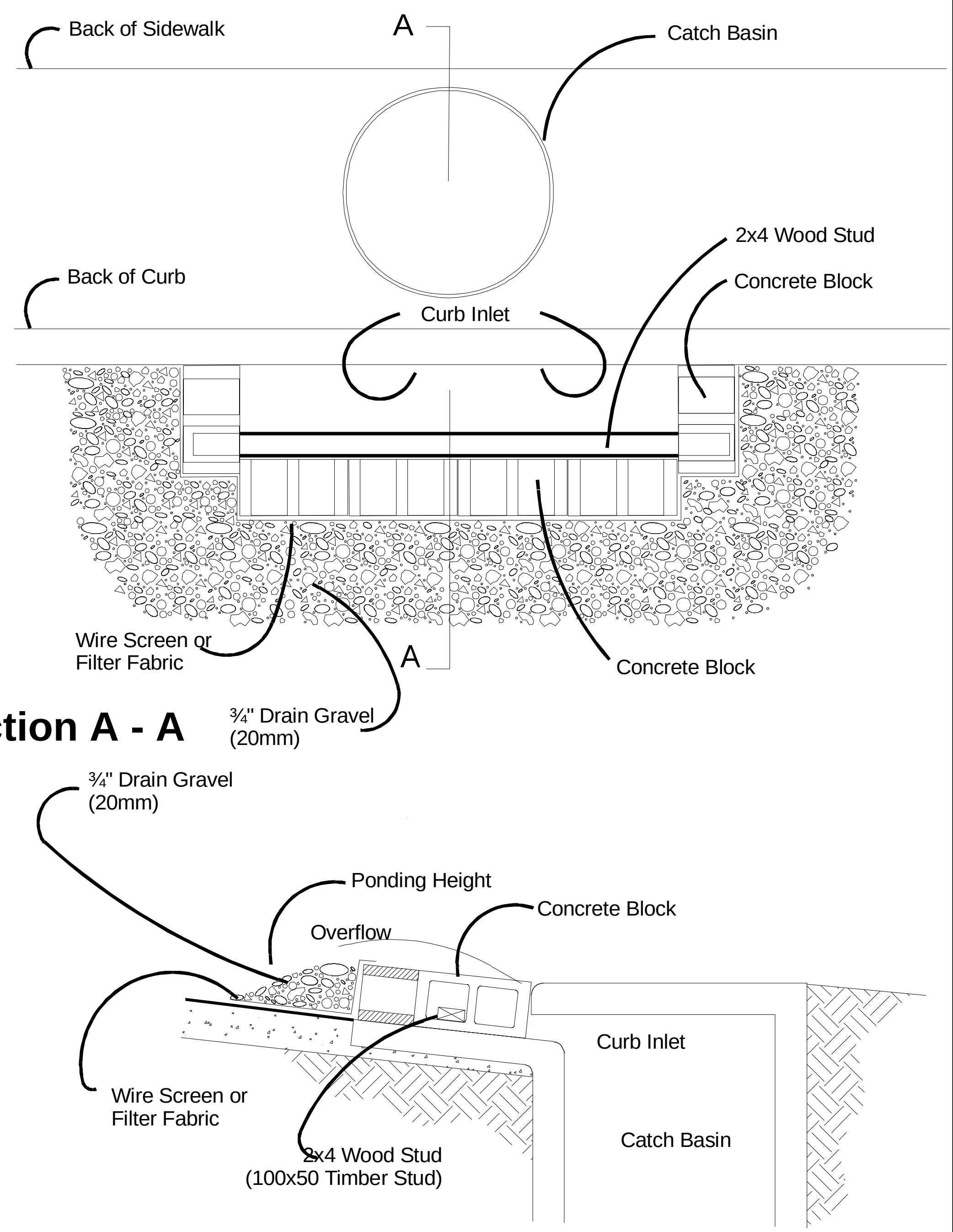
Curb and Gutter Sediment Barrier – Sandbag or rock berm (riprap and aggregate) 3 feet high and 3 feet wide in a horseshoe shape. See Figure 7.3.17.

- Construct a horseshoe shaped berm, faced with coarse aggregate if using riprap, 3 feet high and 3 feet wide, at least 2 feet from the inlet.
- Construct a horseshoe shaped sedimentation trap on the outside of the berm sized to sediment trap standards for protecting a culvert inlet.

Maintenance Standards:

- Catch basin filters should be inspected frequently, especially after storm events. If the insert becomes clogged, it should be cleaned or replaced.
- For systems using stone filters: If the stone filter becomes clogged with sediment, the stones must be pulled away from the inlet and cleaned or replaced. Since cleaning of gravel at a construction site may be difficult, an alternative approach would be to use the clogged stone as fill and put fresh stone around the inlet.
- Do not wash sediment into storm drains while cleaning. Spread all excavated material evenly over the surrounding land area or stockpile and stabilize as appropriate.

Plan View

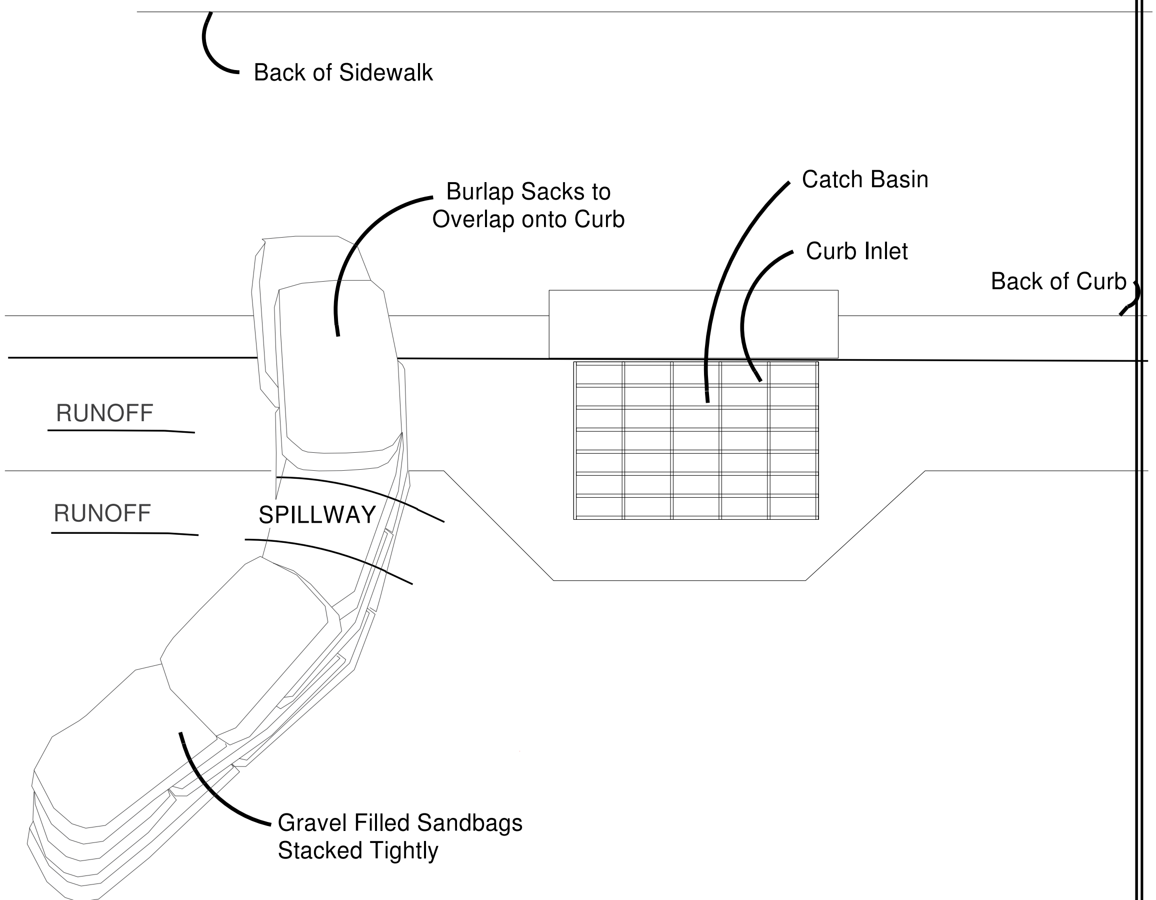


NOTES:
1. Use block and gravel type sediment barrier when curb inlet is located in gently sloping street segment, where water can pond and allow sediment to separate from runoff.
2. Barrier shall allow for overflow from severe storm event.
3. Inspect barriers and remove sediment after each storm event. Sediment and gravel must be removed from the traveled way immediately.

Figure 7.3.16 - Block and Gravel Curb Inlet Protection

Plan View

Figure 7.3.17 – Curb and Gutter Barrier



NOTES:
1. Place curb type sediment barriers on gently sloping street segments, where water can pond and allow sediment to separate from runoff.
2. Sandbags of either burlap or woven `geotextile' fabric, are filled with gravel, layered and packed tightly.
3. Leave a one sandbag gap in the top row to provide a spillway for overflow.
4. Inspect barriers and remove sediment after each storm event. Sediment and gravel must be removed from the traveled way immediately.

BMP C230: Straw Bale Barrier

Purpose: To decrease the velocity of sheet flows and intercept and detain small amounts of sediment from disturbed areas of limited extent, preventing sediment from leaving the site. See Figure 7.3.18 for details on straw bale barriers.

Conditions of Use: Below disturbed areas subject to sheet and rill erosion.

- Straw bales are among the most used and least effective BMPs. The best use of a straw bale is hand spread on the site.
- Where the size of the drainage area is no greater than ¼ acre per 100 feet of barrier length; the maximum slope length behind the barrier is 100 feet; and the maximum slope gradient behind the barrier is 2:1.
- Where effectiveness is required for less than three months.
- Straw bale barriers should not be constructed in streams, unless authorized by the permitting agencies involved in the hydraulic project approval (HPA).
- Straw bale barriers may be used in minor swales or ditch lines where the maximum contributing drainage area is no greater than 2 acres (0.8 Ha).
- Straw bale barriers should not be used where rock or hard surfaces prevent the full and uniform anchoring of the barrier.

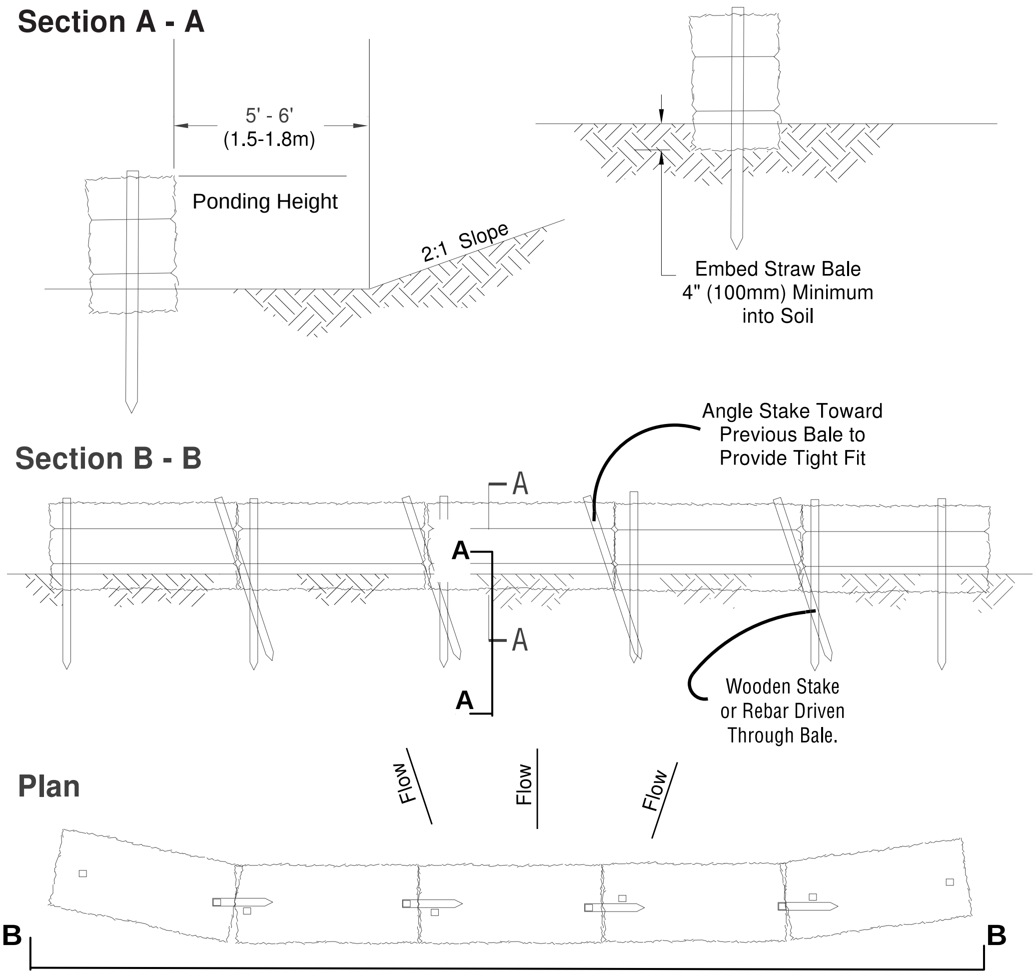
Design and Installation Specifications: Bales shall be placed in a single row, lengthwise on the contour, with ends of adjacent bales tightly abutting one another.

All bales shall be either wire-bound or string-tied. Straw bales shall be installed so that bindings are oriented around the sides rather than along the tops and bottoms of the bales in order to prevent deterioration of the bindings.

- The barrier shall be entrenched and backfilled. A trench shall be excavated the width of a bale and the length of the proposed barrier to a minimum depth of 4 inches. The trench must be deep enough to remove all grass and other material that might allow underflow. After the bales are staked and chinked (filled by wedging), the excavated soil shall be backfilled against the barrier. Backfill soil shall conform to the ground level on the downhill side and shall be built up to 4 inches against the uphill side of the barrier.
- Each bale shall be securely anchored by at least two stakes or re-bars driven through the bale. The first stake in each bale shall be driven toward the previously laid bale to force the bales together. Stakes or re-bars shall be driven deep enough into the ground to securely anchor the bales. Stakes should not extend above the bales but instead should be driven in flush with the top of the bale for safety reasons.
- The gaps between the bales shall be chinked (filled by wedging) with straw to prevent water from escaping between the bales. Loose straw scattered over the area immediately uphill from a straw bale barrier tends to increase barrier efficiency. Wedging must be done carefully in order not to separate the bales.

Maintenance Standards:

- Straw bale barriers shall be inspected immediately after each runoff-producing rainfall and at least daily during prolonged rainfall.
- Close attention shall be paid to the repair of damaged bales, end runs, and undercutting beneath bales.
- Necessary repairs to barriers or replacement of bales shall be accomplished promptly.
- Sediment deposits should be removed after each runoff-producing rainfall. They must be removed when the level of deposition reaches approximately one-half the height of the barrier.
- Any sediment deposits remaining in place after the straw bale barrier is no longer required shall be dressed to conform to the existing grade, prepared and seeded.
- Straw bales used as a temporary straw bale barrier shall be removed after project completion and stabilization to prevent sprouting of unwanted vegetation.



NOTES:
1. The straw bales shall be placed on slope contour.
2. Bales to be placed in a row with the ends tightly abutting.
3. Key in bales to prevent erosion or flow under bales.

Figure 7.3.18 Straw Bale Barrier

BMP C231: Brush Barrier

Purpose: The purpose of brush barriers is to reduce the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

Conditions of Use: Brush barriers may be used downslope of all disturbed areas of less than one-quarter acre.

- Brush barriers are not intended to treat concentrated flows, nor are they intended to treat substantial amounts of overland flow. Any concentrated flows must be conveyed through the drainage system to a sediment pond. The only circumstance in which overland flow can be treated solely by a barrier, rather than by a sediment pond, is when the area draining to the barrier is small.
- Brush barriers should only be installed on contours.

Design and Installation Specifications: Height 2 feet (minimum) to 5 feet (maximum). Width 5 feet at base (minimum) to 15 feet (maximum). Filter fabric (geotextile) may be anchored over the brush berm to enhance the filtration ability of the barrier. Ten-ounce burlap is an adequate alternative to filter fabric.

- Chipped site vegetation, composted mulch, or wood-based mulch (hog fuel) can be used to construct brush barriers.
- A 100 percent biodegradable installation can be constructed using 10-ounce burlap held in place by wooden stakes. Figure 7.3.19 depicts a typical brush barrier.

Maintenance Standards:

- There shall be no signs of erosion or concentrated runoff under or around the barrier. If concentrated flows are bypassing the barrier, it must be expanded or augmented by toed-in filter fabric.
- The dimensions of the barrier must be maintained.

BMP C232: Gravel Filter Berm

Purpose: A gravel filter berm is constructed on rights-of-way or traffic areas within a construction site to retain sediment by using a filter berm of gravel or crushed rock.

Conditions of Use: Where a temporary measure is needed to retain sediment from rights-of-way or in traffic areas on construction sites.

Design and Installation Specifications:

- Berm material shall be ¾ to 3 inches in size, washed well-grade gravel or crushed rock with less than 5 percent fines.
- Spacing of berms:

  Every 300 feet on slopes less than 5 percent
  Every 200 feet on slopes between 5 percent and 10 percent
  Every 100 feet on slopes greater than 10 percent

- Berm dimensions:

  1 foot high with 3:1 side slopes
  8 linear feet per 1 cfs runoff based on the 10-year, 24-hour design storm

Maintenance Standards

- Regular inspection is required. Sediment shall be removed and filter material replaced as needed.

BMP C233: Silt Fence

Purpose: Use of a silt fence reduces the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow. See Figure 7.3.20 for details on silt fence construction.

Conditions of Use:

- Silt fence may be used downslope of all disturbed areas. Silt fence is not intended to treat concentrated flows, nor is it intended to treat substantial amounts of overland flow. Any concentrated flows must be conveyed through the drainage system to a sediment pond. The only circumstance in which overland flow can be treated solely by a silt fence, rather than by a sediment pond, is when the area draining to the fence is one acre or less and flow rates are less than 0.5 cfs.
- Silt fences should not be constructed in streams or used in V-shaped ditches. They are not an adequate method of silt control for anything deeper than sheet or overland flow.

Design and Installation Specifications: Drainage area of 1 acre or less or in combination with sediment basin in a larger site.

- Maximum slope steepness (normal (perpendicular) to fence line) 1:1.
- Maximum sheet or overland flow path length to the fence of 100 feet.
- No flows greater than 0.5 cfs.
- The geotextile used shall meet the following standards. All geotextile properties listed below are minimum average roll values (i.e., the test result for any sampled roll in a lot shall meet or exceed the values shown in Table 7.3.10).

Table 7.3.10 Geotextile Standards

Polymeric Mesh AOS (ASTM D4751)	0.60 mm maximum for slit film wovens (#30 sieve). 0.30 mm maximum for all other geotextile types (#50 sieve). 0.15 mm minimum for all fabric types (#100 sieve).
Water Permittivity (ASTM D4491)	0.02 sec^{-1} minimum
Grab Tensile Strength (ASTM D4632)	180 lbs. Minimum for extra strength fabric. 100 lbs minimum for standard strength fabric.
Grab Tensile Strength (ASTM D4632)	30% maximum
Ultraviolet Resistance (ASTM D4355)	70% minimum

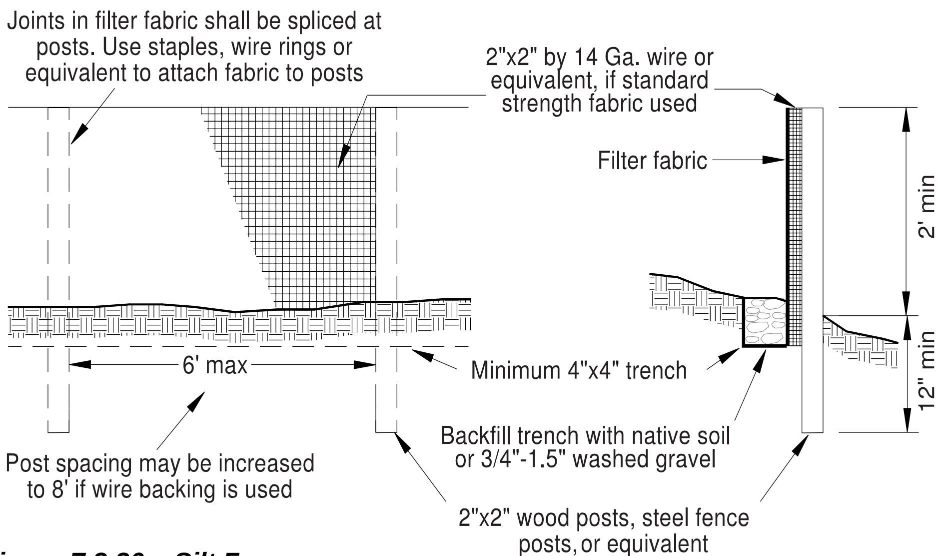


Figure 7.3.20 – Silt Fence

Design and Installation Specifications:

- Standard strength fabrics shall be supported with wire mesh, chicken wire, 2-inch x 2-inch wire, safety fence, or jute mesh to increase the strength of the fabric. Silt fence materials are available that have synthetic mesh backing attached.
- Filter fabric material shall contain ultraviolet ray inhibitors and stabilizers to provide a minimum of six months of expected usable construction life at a temperature range of 0°F. to 120°F.
- 100 percent biodegradable silt fence is available that is strong, long lasting, and can be left in place after the project is completed, if permitted by local regulations.
- The contractor shall install and maintain temporary silt fences at the locations shown in the Plans. The silt fences shall be constructed in the areas of clearing, grading, or drainage prior to starting those activities. A silt fence shall not be considered temporary if the silt fence must function beyond the life of the contract. The silt fence shall prevent soil carried by runoff water from going beneath, through, or over the top of the silt fence, but shall allow the water to pass through the fence.
- The minimum height of the top of silt fence shall be 2 feet and the maximum height shall be 2½ feet above the original ground surface.
- The geotextile shall be sewn together at the point of manufacture, or at an approved location as determined by the Engineer, to form geotextile lengths as required. All sewn seams shall be located at a support post. Alternatively, two sections of silt fence can be overlapped, provided the Contractor can

demonstrate, to the satisfaction of the Engineer, that the overlap is long enough and that the adjacent fence sections are close enough together to prevent silt laden water from escaping through the fence at the overlap.

- The geotextile shall be attached on the up-slope side of the posts and support system with staples, wire, or in accordance with the manufacturer's recommendations. The geotextile shall be attached to the posts in a manner that reduces the potential for geotextile tearing at the staples, wire, or other connection device. Silt fence back-up support for the geotextile in the form of a wire or plastic mesh is dependent on the properties of the geotextile selected for use. If wire or plastic back-up mesh is used, the mesh shall be fastened securely to the up-slope of the posts with the geotextile being up-slope of the mesh back-up support.

- The geotextile at the bottom of the fence shall be buried in a trench to a minimum depth of 4 inches below the ground surface. The trench shall be backfilled and the soil tamped in place over the buried portion of the geotextile, such that no flow can pass beneath the fence and scouring can not occur. When wire or polymeric back-up support mesh is used, the wire or polymeric mesh shall extend into the trench a minimum of 3 inches.

- The fence posts shall be placed or driven a minimum of 18 inches. A minimum depth of 12 inches is allowed if topsoil or other soft subgrade soil is not present and a minimum depth of 18 inches cannot be reached. Fence post depths shall be increased by 6 inches if the fence is located on slopes of 3:1 or steeper and the slope is perpendicular to the fence. If required post depths cannot be obtained, the posts shall be adequately secured by bracing or guying to prevent overturning of the fence due to sediment loading.

- Silt fences shall be located on contour as much as possible, except at the ends of the fence, where the fence shall be turned uphill such that the silt fence captures the runoff water and prevents water from flowing around the end of the fence.

- If the fence must cross contours, with the exception of the ends of the fence, gravel check dams placed perpendicular to the back of the fence shall be used to minimize concentrated flow and erosion along the back of the fence. The gravel check dams shall be approximately 1-foot deep at the back of the fence. It shall be continued perpendicular to the fence at the same elevation until the top of the check dam intercepts the ground surface behind the fence. The gravel check dams shall consist of crushed surfacing base course, gravel backfill for walls, or shoulder ballast. The gravel check dams shall be located every 10 feet along the fence where the fence must cross contours. The slope of the fence line where contours must be crossed shall not be steeper than 3:1.

- Wood, steel or equivalent posts shall be used. Wood posts shall have minimum dimensions of 2 inches by 2 inches by 3 feet minimum length, and shall be free of defects such as knots, splits, or gouges. Steel posts shall consist of either size No. 6 rebar or larger, ASTM A 120 steel pipe with a minimum diameter of 1-inch, U, T, L, or C shape steel posts with a minimum weight of 1.35 lbs./ft. or other steel posts having equivalent strength and bending resistance to the post sizes listed. The spacing of the support posts shall be a maximum of 6 feet.

- Fence back-up support, if used, shall consist of steel wire with a maximum mesh spacing of 2 inches, or a prefabricated polymeric mesh. The strength of the wire or polymeric mesh shall be equivalent to or greater than 180 lbs. grab tensile strength. The polymeric mesh must be as resistant to ultraviolet radiation as the geotextile it supports.
- Silt fence installation using the slicing method specification details follow. Refer to Figure 7.3.21 for slicing method details.
- The base of both end posts must be at least 2 to 4 inches above the top of the silt fence fabric on the middle posts for ditch checks to drain properly. Use a hand level or string level, if necessary, to mark base points before installation.
- Install posts 3 to 4 feet apart in critical retention areas and 6 to 7 feet apart in standard applications.
- Install posts 24 inches deep on the downstream side of the silt fence, and as close as possible to the fabric, enabling posts to support the fabric from upstream water pressure.
- Install posts with the nipples facing away from the silt fence fabric.
- Attach the fabric to each post with three ties, all spaced within the top 8 inches of the fabric. Attach each tie diagonally 45 degrees through the fabric, with each puncture at least 1 inch vertically apart. In addition, each tie should be positioned to hang on a post nipple when tightening to prevent sagging.
- Wrap approximately 6 inches of fabric around the end posts and secure with 3 ties.
- No more than 24 inches of a 36-inch fabric is allowed above ground level.
- The rope lock system must be used in all ditch check applications.
- The installation should be checked and corrected for any deviation before compaction. Use a flat-bladed shovel to tuck fabric deeper into the ground if necessary.
- Compaction is vitally important for effective results. Compact the soil immediately next to the silt fence fabric with the front wheel of the tractor, skid steer, or roller exerting at least 60 pounds per square inch. Compact the upstream side first and then each side twice for a total of four trips.

Maintenance Standards:

- Any damage shall be repaired immediately.
- If concentrated flows are evident uphill of the fence, they must be intercepted and conveyed to a sediment pond.

- It is important to check the uphill side of the fence for signs of the fence clogging and acting as a barrier to flow and then causing channelization of flows parallel to the fence. If this occurs, replace the fence or remove the trapped sediment.
- Sediment deposits shall either be removed when the deposit reaches approximately one-third the height of the silt fence, or a second silt fence shall be installed.
- If the filter fabric (geotextile) has deteriorated due to ultraviolet breakdown, it shall be replaced.

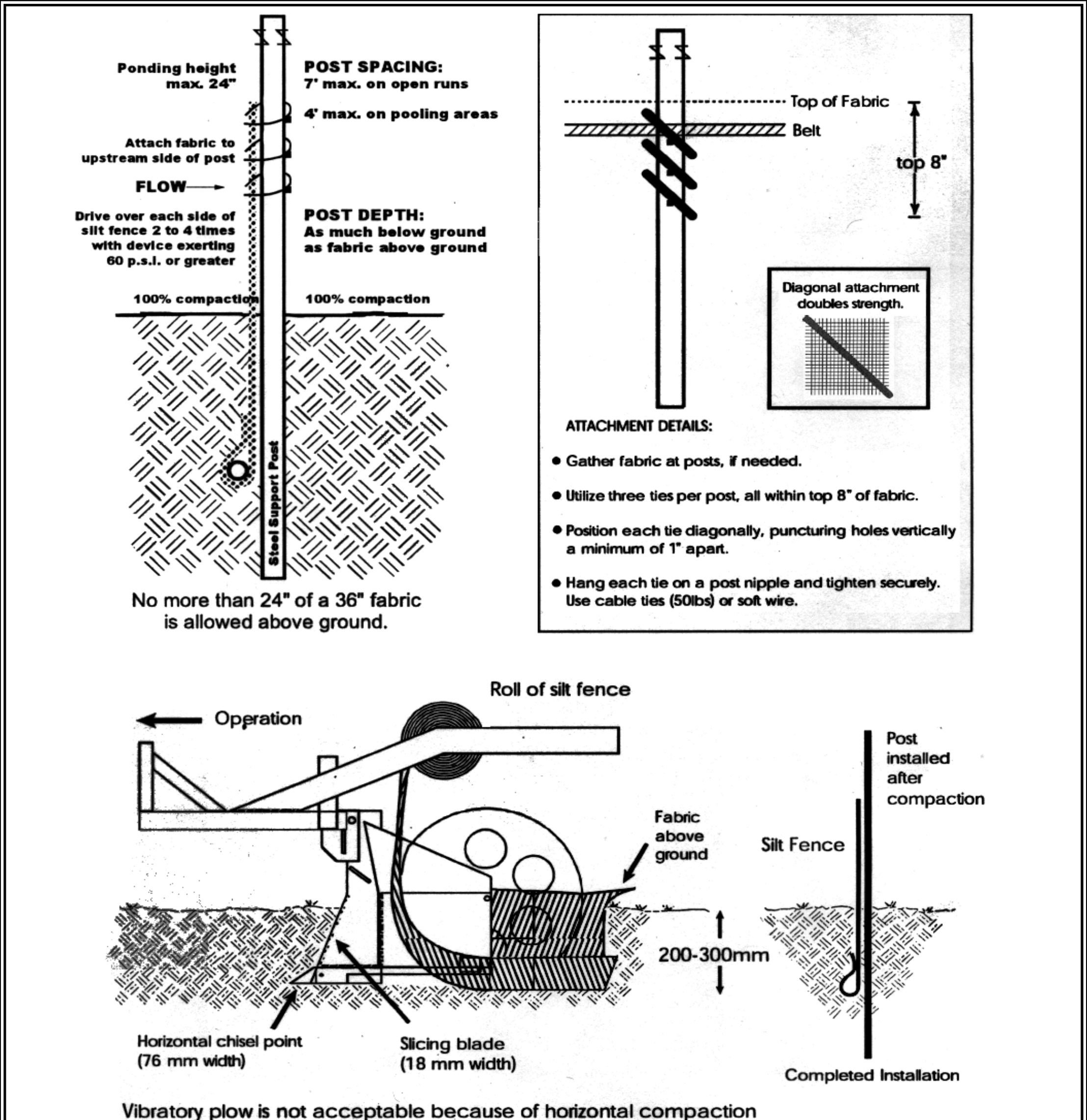


Figure 7.3.21 – Silt Fence Installation by Slicing Method

BMP C234: Vegetated Strip

Purpose: Vegetated strips reduce the transport of coarse sediment from a construction site by providing a temporary physical barrier to sediment and reducing the runoff velocities of overland flow.

Conditions of Use:

- Vegetated strips may be used downslope of all disturbed areas.
- Vegetated strips are not intended to treat concentrated flows, nor are they intended to treat substantial amounts of overland flow. Any concentrated flows must be conveyed through the drainage system to a sediment pond. The only circumstance in which overland flow can be treated solely by a strip, rather than by a sediment pond, is when the following criteria are met (see Table 7.3.11):

Table 7.3.11 - Vegetated Strips

Average Slope	Slope Percent	Flowpath Length
1.5H:1V or less	67% or less	100 feet
2H:1V or less	50% or less	115 feet
4H:1V or less	25% or less	150 feet
6H:1V or less	16.7% or less	200 feet
10H:1V or less	10% or less	250 feet

Design and Installation Specifications: The vegetated strip shall consist of a minimum of a 25-foot wide continuous strip of dense vegetation with a permeable topsoil. Grass-covered, landscaped areas are generally not adequate because the volume of sediment overwhelms the grass. Ideally, vegetated strips shall consist of undisturbed native growth with a well-developed soil that allows for infiltration of runoff.

- The slope within the strip shall not exceed 4H:1V.
- The uphill boundary of the vegetated strip shall be delineated with clearing limits.

Maintenance Standards: Any areas damaged by erosion or construction activity shall be seeded immediately and protected by mulch.

- If more than 5 feet of the original vegetated strip width has had vegetation removed or is being eroded, sod must be installed.
- If there are indications that concentrated flows are traveling across the buffer, surface water controls must be installed to reduce the flows entering the buffer, or additional perimeter protection must be installed.

BMP C235: Straw Wattles

Purpose: Straw wattles are temporary erosion and sediment control barriers consisting of straw that is wrapped in biodegradable tubular plastic or similar encasing material. They reduce the velocity and can spread the flow of rill and sheet runoff, and can capture and retain sediment. Straw wattles are typically 8 to 10 inches in diameter and 25 to 30 feet in length. The wattles are placed in shallow trenches and staked along the contour of disturbed or newly constructed slopes. See Figure 7.3.22 for typical construction details.

Conditions of Use:

- Disturbed areas that require immediate erosion protection.
- Exposed soils during the period of short construction delays, or over winter months.
- On slopes requiring stabilization until permanent vegetation can be established.
- Straw wattles are effective for one to two seasons.
- If conditions are appropriate, wattles can be staked to the ground using willow cuttings for added revegetation.
- Rilling can occur beneath wattles if not properly entrenched and water can pass between wattles if not tightly abutted together.

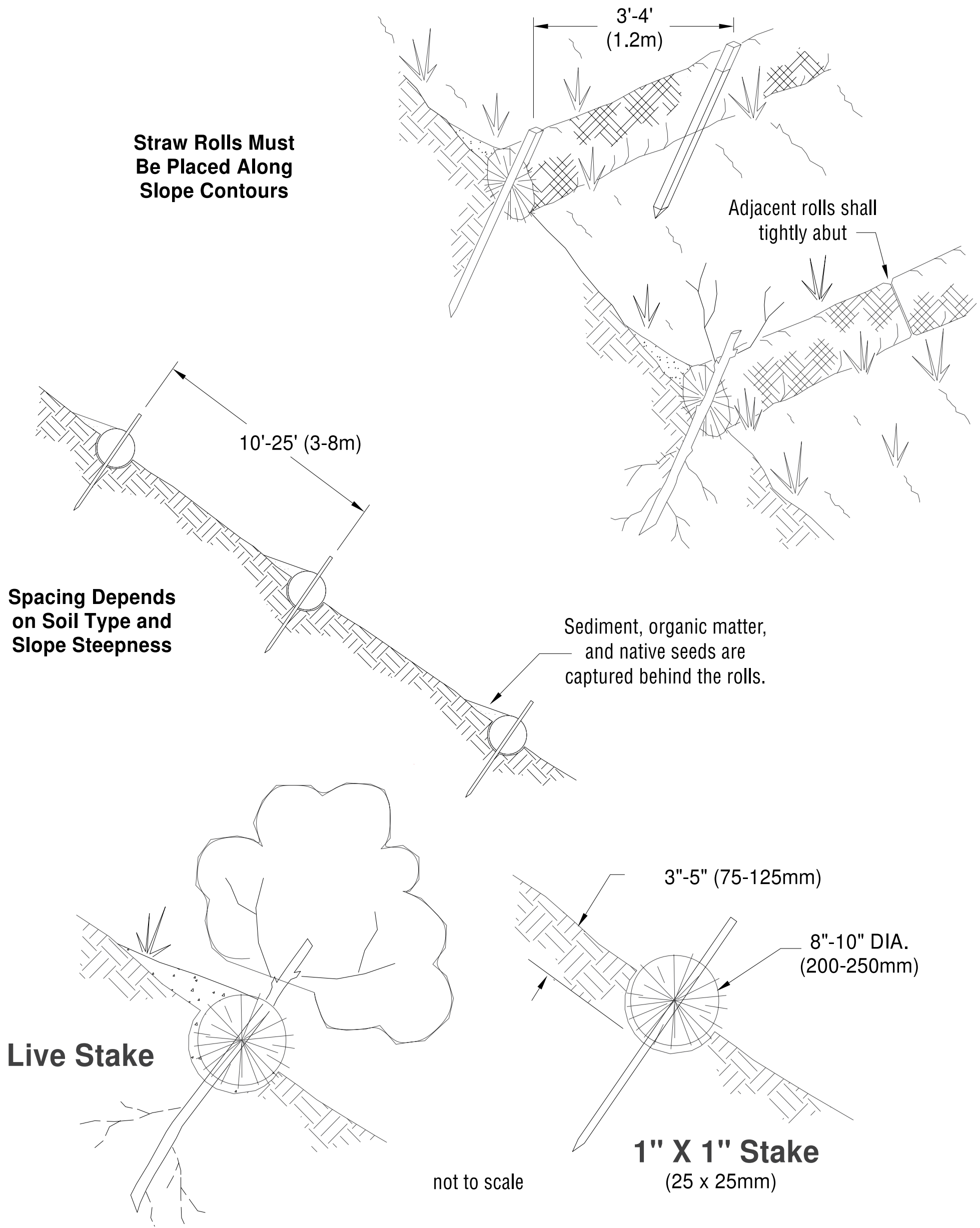
Design Criteria:

- It is critical that wattles are installed perpendicular to the flow direction and parallel to the slope contour.
- Narrow trenches should be dug across the slope on contour to a depth of 3 to 5 inches on clay soils and soils with gradual slopes. On loose soils, steep slopes, and areas with high rainfall, the trenches should be dug to a depth of 5 to 7 inches, or ½ to 2/3 of the thickness of the wattle.
- Start building trenches and installing wattles from the base of the slope and work up. Excavated material should be spread evenly along the uphill slope and compacted using hand tamping or other methods.
- Construct trenches at contour intervals of 3 to 30 feet apart depending on the steepness of the slope, soil type, and rainfall. The steeper the slope the closer together the trenches.
- Install the wattles snugly into the trenches and abut tightly end to end. Do not overlap the ends.
- Install stakes at each end of the wattle, and at 4-foot centers along entire length of wattle.
- If required, install pilot holes for the stakes using a straight bar to drive holes through the wattle and into the soil.
- At a minimum, wooden stakes should be approximately ¾ x ¾ x 24 inches. Willow cuttings or 3/8-inch rebar can also be used for stakes.

- Stakes should be driven through the middle of the wattle, leaving 2 to 3 inches of the stake protruding above the wattle.

Maintenance Standards:

- Wattles may require maintenance to ensure they are in contact with soil and thoroughly entrenched, especially after significant rainfall on steep sandy soils.
- Inspect the slope after significant storms and repair any areas where wattles are not tightly abutted or water has scoured beneath the wattles.



NOTE:
Straw roll installation requires the placement and secure staking of the roll in a trench, 3”x5” (75-125mm) deep, dug on contour. Runoff must not be allowed to run under or around roll.

Figure 7.3.22 - Straw Wattles

BMP C240: Sediment Trap

Purpose: A sediment trap is a small temporary ponding area with a gravel outlet used to collect and store sediment from sites cleared and/or graded during construction. Sediment traps, along with other perimeter controls, shall be installed before any land disturbance takes place in the drainage area.

Conditions of Use: Prior to leaving a construction site, stormwater runoff must pass through a sediment pond or trap or other appropriate sediment removal best management practice. Non-engineered sediment traps may be used on-site prior to an engineered sediment trap or sediment pond to provide additional sediment removal capacity.

It is intended for use on sites where the tributary drainage area is less than 3 acres, with no unusual drainage features, and a projected build-out time of six months or less. The sediment trap is a temporary measure (with a design life of approximately 6 months) and shall be maintained until the site area is permanently protected against erosion by vegetation and/or structures.

Sediment traps and ponds are only effective in removing sediment down to about the medium silt size fraction. Runoff with sediment of finer grades (fine silt and clay) will pass through untreated, emphasizing the need to control erosion to the maximum extent first.

Whenever possible, sediment-laden water shall be discharged into onsite, relatively level, vegetated areas (see BMP C234 – Vegetated Strip). This is the only way to effectively remove fine particles from runoff unless chemical treatment or filtration is used. This can be particularly useful after initial treatment in a sediment trap or pond. The areas of release must be evaluated on a site-by-site basis in order to determine appropriate locations for and methods of releasing runoff. Vegetated wetlands shall not be used for this purpose. Frequently, it may be possible to pump water from the collection point at the downhill end of the site to an upslope vegetated area. Pumping shall only augment the treatment system, not replace it, because of the possibility of pump failure or runoff volume in excess of pump capacity.

All projects that are constructing permanent facilities for runoff quantity control should use the rough-graded or final-graded permanent facilities for traps and ponds. This includes combined facilities and infiltration facilities. When permanent facilities are used as temporary sedimentation facilities, the surface area requirement of a sediment trap or pond must be met. If the surface area requirements are larger than the surface area of the permanent facility, then the trap or pond shall be enlarged to comply with the surface area requirement. The permanent pond shall also be divided into two cells as required for sediment ponds.

Either a permanent control structure or the temporary control structure (described in BMP C241, Temporary Sediment Pond) can be used. If a permanent control structure is used, it may be advisable to partially restrict the lower orifice with gravel to increase residence time while still allowing dewatering of the pond. A shut-off valve may be added to the control structure to allow complete retention of stormwater in emergency situations. In this case, an emergency overflow weir must be added.

A skimmer may be used for the sediment trap outlet if approved by the Jurisdiction.

Design and Installation Specifications:

See Figures 7.3.23 and 7.3.24 for details.

If permanent runoff control facilities are part of the project, they should be used for sediment retention.

To determine the sediment trap geometry, first calculate the design surface area (SA) of the trap, measured at the invert of the weir. Use the following equation:

$SA = FS(Q_2/Vs)$

Where,

Q_2 = Design inflow based on the peak discharge from the developed 2-year runoff event from the contributing drainage area as computed in the hydrologic analysis. The 10-year peak flow shall be used if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection. If no hydrologic analysis is required, the Rational Method may be used.

V_s = The settling velocity of the soil particle of interest. The 0.02 mm (medium silt) particle with an assumed density of 2.65 g/cm^3 has been selected as the particle of interest and has a settling velocity (Vs) of 0.00096 ft/sec.

FS = A safety factor of 2 to account for non-ideal settling.

Therefore, the equation for computing surface area becomes:

$SA = 2 \times Q_2/0.00096$ or 2080 square feet per cfs of inflow

Note: *Even if permanent facilities are used, they must still have a surface area that is at least as large as that derived from the above formula. If they do not, the pond must be enlarged.*

- To aid in determining sediment depth, all sediment traps shall have a staff gauge with a prominent mark 1-foot above the bottom of the trap.
- Sediment traps may not be feasible on utility projects due to the limited work space or the short-term nature of the work. Portable tanks may be used in place of sediment traps for utility projects.

Maintenance Standards:

- Sediment shall be removed from the trap when it reaches 1-foot in depth.
- Any damage to the pond embankments or slopes shall be repaired.

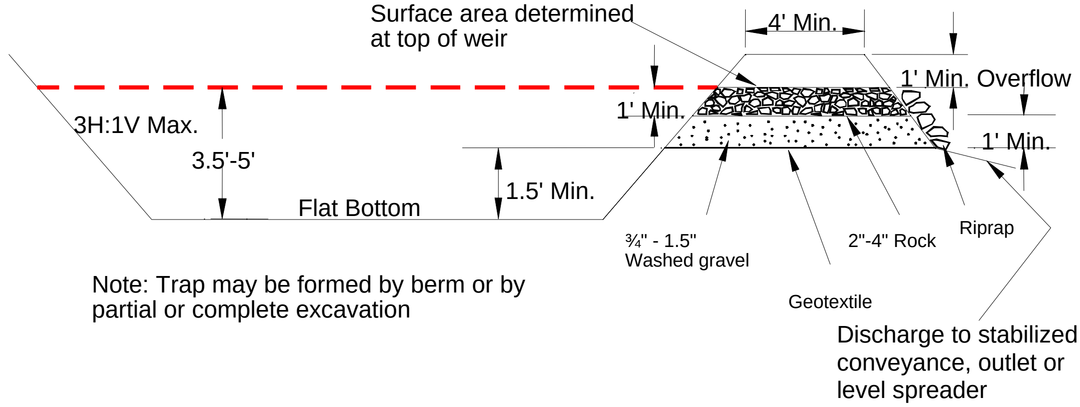


Figure 7.3.23 Cross-Section of Sediment Trap

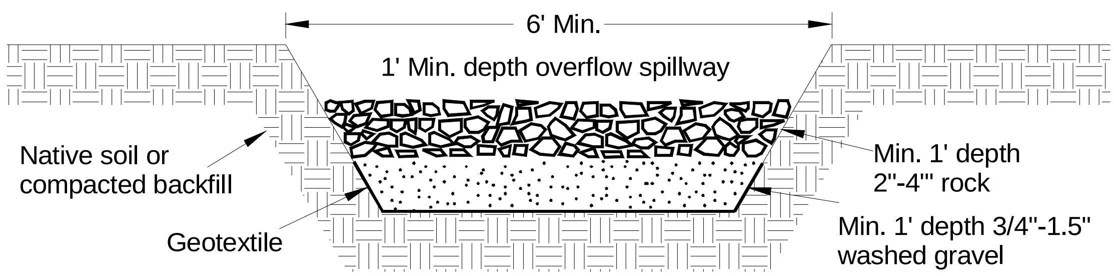


Figure 7.3.24 Sediment Trap Outlet

BMP C241: Temporary Sediment Pond

Purpose: Sediment ponds remove sediment from runoff originating from disturbed areas of the site. Sediment ponds are typically designed to remove sediment no smaller than medium silt (0.02 mm). Consequently, they usually reduce turbidity only slightly.

Conditions of Use

Conditions of Use: Prior to leaving a construction site, stormwater runoff must pass through a sediment pond or other appropriate sediment removal best management practice.

A sediment pond shall be used where the contributing drainage area is 3 acres or more. Ponds must be used in conjunction with erosion control practices to reduce the amount of sediment flowing into the basin.

Design and Installation Specifications: Sediment basins should be installed only on sites where failure of the structure would not result in loss of life, damage to homes or buildings, or interruption of use or service of public roads or utilities. Also, sediment traps and ponds are attractive to children and can be very dangerous. Compliance with local ordinances regarding health and safety must be addressed. If fencing of the pond is required, the type of fence and its location shall be shown on the ESC plan.

- Structures having a maximum storage capacity at the top of the dam of 10 acre-ft (435,600 ft3) or more are subject to the Washington Dam Safety Regulations (Chapter 173-175 WAC).
- See Figures 7.3.25, 7.3.26, and 7.3.27 for details.
- If permanent runoff control facilities are part of the project, they should be used for sediment retention. The surface area requirements of the sediment basin must be met. This may require enlarging the permanent basin to comply with the surface area requirements. If a permanent control structure is used, it may be advisable to partially restrict the lower orifice with gravel to increase residence time while still allowing dewatering of the basin.
- Use of infiltration facilities for sedimentation basins during construction tends to clog the soils and reduce their capacity to infiltrate. If infiltration facilities are to be used, the sides and bottom of the facility should only be rough excavated to a minimum of 2 feet above final grade. Final grading of the infiltration facility shall occur only when all contributing drainage areas are fully stabilized. The infiltration pretreatment facility should be fully constructed and used with the sedimentation basin to help prevent clogging.

Determining Pond Geometry

The storage capacity of the basin may be sized by obtaining the discharge from the hydrologic calculations of the peak flow for the 2-year runoff event (Q2). The 10-year peak flow should be used if the project size, expected timing and duration of construction, or downstream conditions warrant a higher level of protection. If no hydrologic analysis is required, the Rational Method may be used.

Alternatively, the sediment basin, as measured from the bottom of the basin to the principal outlet, shall have at least a capacity equivalent to 3,600 cubic feet of storage per acre draining into the sediment basin.

Determine the required surface area at the top of the riser pipe with the equation:

$SA = 2 \times Q_2/0.00096$, or 2080 square feet per cfs of inflow

See BMP C240 for more information on the derivation of the surface area calculation. The basic geometry of the pond can now be determined using the following design criteria:

- Required surface area SA (from Step 2 above) at top of riser.
- Minimum 3.5-foot depth from top of riser to bottom of pond.
- Maximum 3:1 interior side slopes and maximum 2:1 exterior slopes. The interior slopes can be increased to a maximum of 2:1 if fencing is provided at or above the maximum water surface.
- One foot of freeboard between the top of the riser and the crest of the emergency spillway.
- Flat bottom.
- Minimum 1-foot deep spillway.
- The length of the basin, as determined by measuring the distance between the inlet and the outlet, shall be between 3 and 6 times the width of the basin.

Sizing of Discharge Mechanisms

The outlet for the basin consists of a combination of principal and emergency spillways. These outlets must pass the peak runoff expected from the contributing drainage area for a 100-year storm. If, due to site conditions and basin geometry, a separate emergency spill-way is not feasible, the principal spillway must pass the entire peak runoff expected from the 100-year storm. However, an attempt to provide a separate emergency spillway should always be made. The runoff calculations should be based on the site conditions during construction. The flow through the dewatering orifice cannot be utilized when calculating the 100-year storm elevation because of its potential to become clogged; therefore, available spillway storage must begin at the principal spillway riser crest.

The principal spillway designed by the procedures contained in this standard will result in some reduction in the peak rate of runoff. However, the riser outlet design will not adequately control the basin discharge to the predevelopment discharge limitations. However, if the basin for a permanent stormwater detention pond is used for a temporary sedimentation basin, the control structure for the permanent pond can be used to maintain predevelopment discharge limitations. The size of the basin, the expected life of the construction project, the anticipated downstream effects and the anticipated weather conditions during construction, should be considered to determine the need for additional discharge control. See Figure 7.3.28 for riser inflow curves.

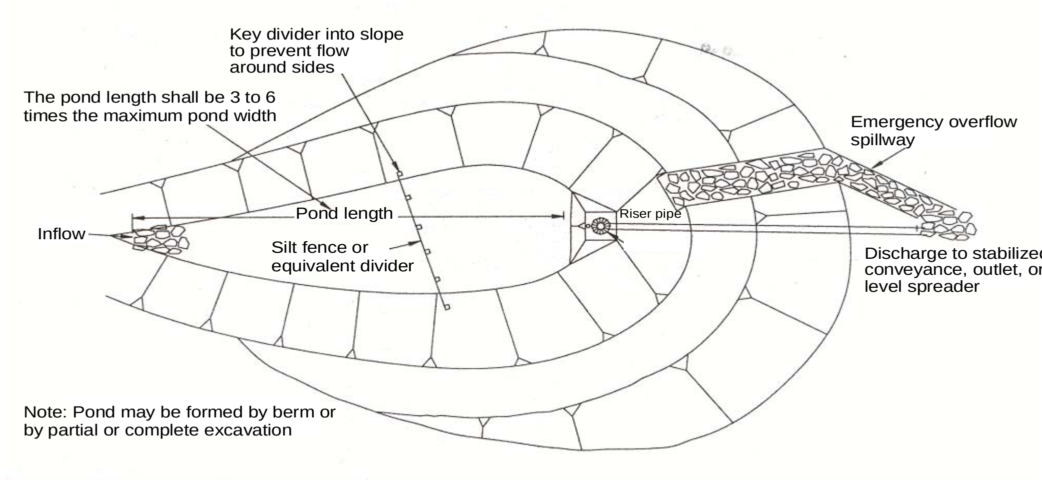


Figure 7.3.25 – Sediment Pond Plan View

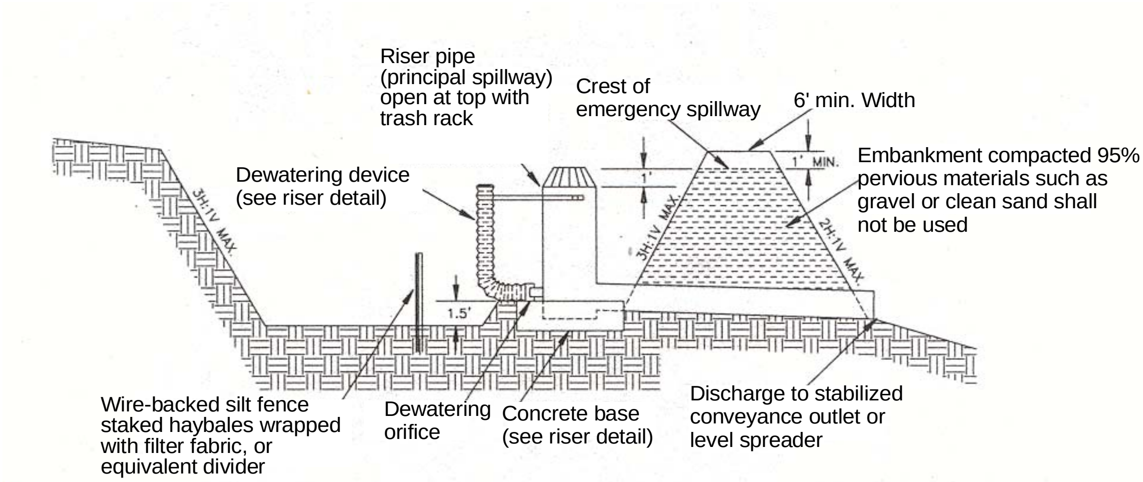


Figure 7.3.26 - Sediment Pond Cross Section

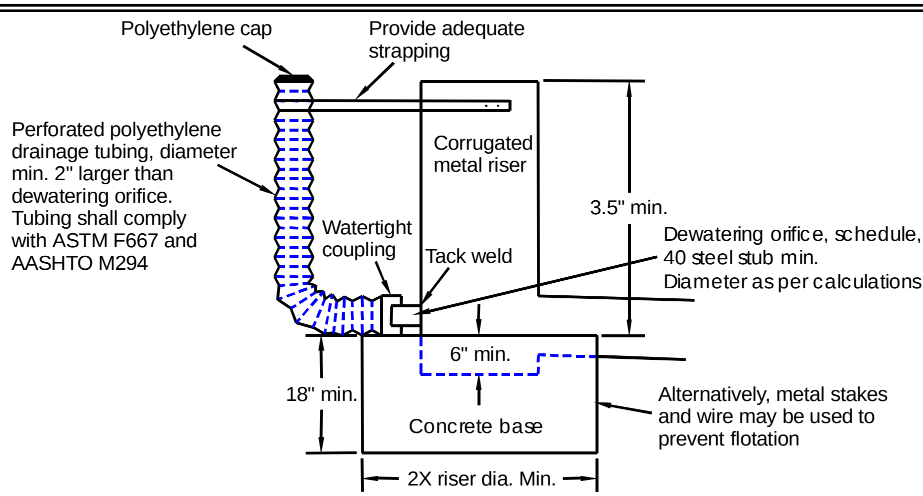


Figure 7.3.27 – Sediment Pond Riser Detail

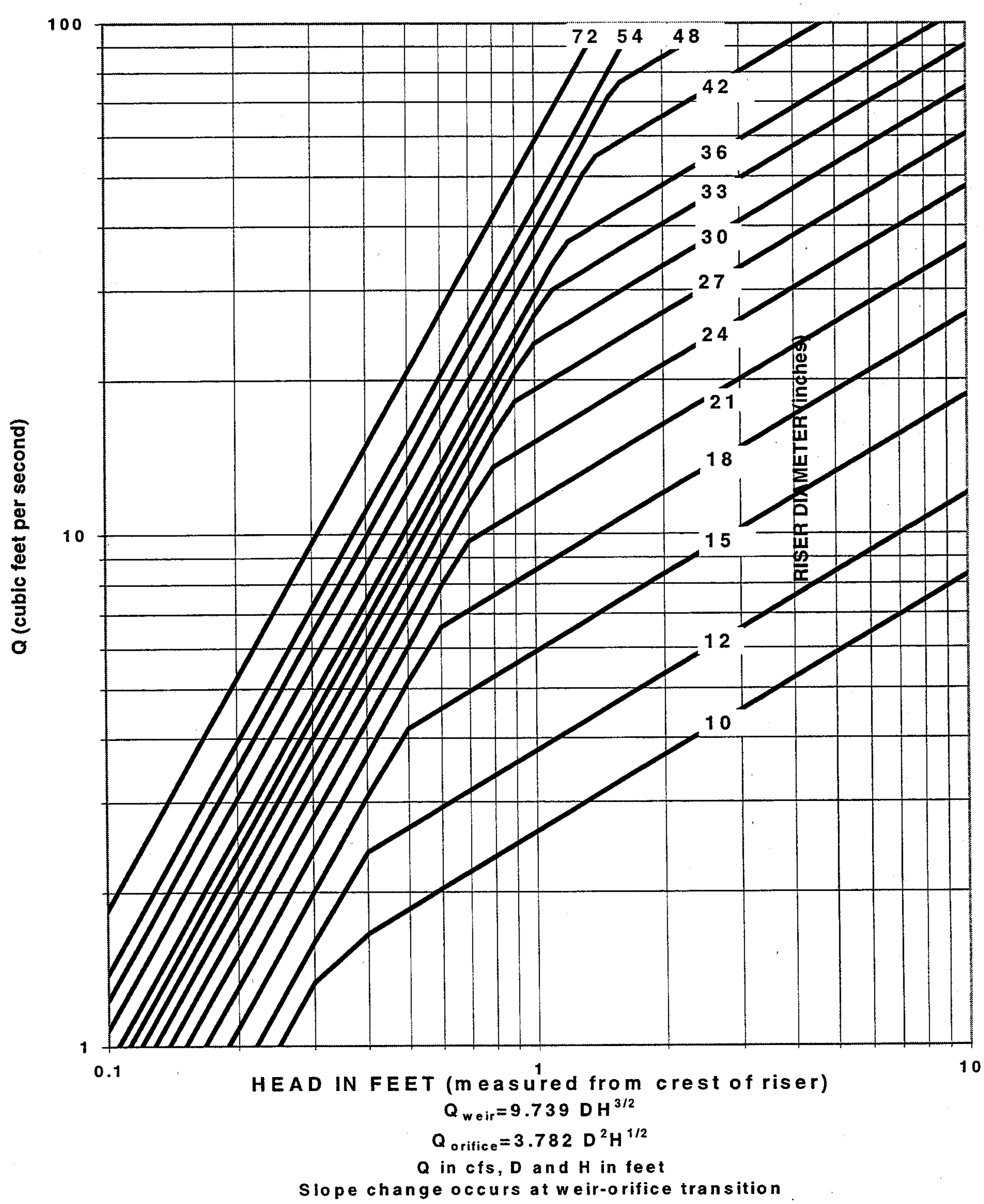


Figure 7.3.28 - Riser Inflow Curves

Principal Spillway: Determine the required diameter for the principal spillway (riser pipe). The diameter shall be the minimum necessary to pass the pre-developed 10-year peak flow (Q10). Use Figure 4.28 to determine this diameter (h = 1-foot). Note: A permanent control structure may be used instead of a temporary riser.

Emergency Overflow Spillway: Determine the required size and design of the emergency overflow spillway for the developed 100-year peak flow using the method contained in Chapter 4.

Dewatering Orifice: Determine the size of the dewatering orifice(s) (minimum 1-inch diameter) using a modified version of the discharge equation for a vertical orifice and a basic equation for the area of a circular orifice. Determine the required area of the orifice with the following equation:

$$A_o = \frac{A_s(2h)^{0.5}}{0.6\text{x}3600Tg^{0.5}}$$

where	Ao	=	orifice area (square feet)
	As	=	pond surface area (square feet)
	h	=	head of water above orifice (height of riser in feet)
	T	=	dewatering time (24 hours)
	g	=	acceleration of gravity (32.2 feet/second2)

Convert the required surface area to the required diameter D of the orifice:

The vertical, perforated tubing connected to the dewatering orifice must be at least 2 inches larger in diameter than the orifice to improve flow characteristics. The size and number of perforations in the tubing should be large enough so that the tubing does not restrict flow. The orifice should control the flow rate.

Additional Design Specifications

The pond should be divided into two roughly equal volume cells by a permeable divider that will reduce turbulence while allowing movement of water between cells. The divider should be at least one-half the height of the riser and a minimum of one foot below the top of the riser. Wire-backed, 2- to 3-foot high, extra strength filter fabric supported by treated 4”x4”s can be used as a divider. Alternatively, staked straw bales wrapped with filter fabric (geotextile) may be used. If the pond is more than 6 feet deep, a different mechanism must be proposed. A riprap embankment is one acceptable method of separation for deeper ponds. Other designs that satisfy the intent of this provision are allowed as long as the divider is permeable, structurally sound, and designed to prevent erosion under or around the barrier.

To aid in determining sediment depth, one-foot intervals should be prominently marked on the riser.

If an embankment of more than 6 feet is proposed, the pond must comply with the criteria contained in Chapter 5 regarding dam safety for detention BMPs.

The most common structural failure of sedimentation basins is caused by piping. Piping refers to two phenomena: (1) water seeping through fine-grained soil, eroding the soil grain by grain and forming pipes or tunnels; and, (2) water under pressure flowing upward through a granular soil with a head of sufficient magnitude to cause soil grains to lose contact and capability for support.

The most critical construction sequences to prevent piping will be:

- Tight connections between riser and barrel and other pipe connections.
- Adequate anchoring of riser.
- Proper soil compaction of the embankment and riser footing.
- Proper construction of anti-seep devices.

Maintenance Standards:

- Sediment shall be removed from the pond when it reaches 1–foot in depth.
- Any damage to the pond embankments or slopes shall be repaired.

Appendix 7A - Resource Materials

- Association of General Contractors of Washington, *Water Quality Manual*.
- Clark County Conservation District, *Erosion and Runoff Control*, January 1981.
- King County Conservation District, *Construction and Erosion Control*, December 1981.
- *King County Department of Transportation Road Maintenance BMP Manual (Final Draft)*, May 1998.
- *King County Surface Water Design Manual*, September 1998.
- *Maryland Erosion and Sedimentation Control Manual*, 1983.
- *Michigan State Guidebook for Erosion and Sediment Control*, 1975.
- Reinelt, Loren, *Construction Site Erosion and Sediment Control Inspector Training Manual*, Center for Urban Water Resources Management, University of Washington, October 1991.
- Snohomish County Addendum to the 1992 *Ecology Stormwater Management Manual for the Puget Sound Basin*, September 1998.
- Reinelt, Loren, *Processes, Procedures, and Methods to Control Pollution Resulting from all Construction Activity*, Center for Urban Water Resources Management, University of Washington, October 1991.
- *Virginia Erosion and Sediment Control Handbook*, 2nd Edition, 1980.

Appendix 7B - Recommended Standard Notes for Erosion/Sedimentation Control (ESC) Plans

The following standard notes are suggested for use in erosion/ sedimentation control (ESC) plans. Local jurisdictions may have other mandatory notes for construction plans that are applicable. Plans should also identify with phone numbers the person or firm responsible for the preparation of and maintenance of the erosion control plan.

Standard Notes

Approval of this ESC plan does not constitute an approval of permanent road or drainage design (e.g. size and location of roads, pipes, restrictors, channels, retention facilities, utilities, etc.).

The implementation of these ESC plans and the construction, maintenance, replacement, and upgrading of these ESC facilities is the responsibility of the applicant/contractor until all construction is completed and approved and vegetation/landscaping is established.

The boundaries of the clearing limits shown on this plan shall be clearly flagged in the field prior to construction. During the construction period, no disturbance beyond the flagged clearing limits shall be permitted. The flagging shall be maintained by the applicant/contractor for the duration of construction.

The ESC facilities shown on this plan must be constructed in conjunction with all clearing and grading activities, and in such a manner as to insure that sediment and sediment laden water do not enter the drainage system, roadways, or violate applicable water standards.

The ESC facilities shown on this plan are the minimum requirements for anticipated site conditions. During the construction period, these ESC facilities shall be upgraded as needed for unexpected storm events and to ensure that sediment and sediment-laden water do not leave the site.

The ESC facilities shall be inspected daily by the applicant/contractor and maintained as necessary to ensure their continued functioning.

The ESC facilities on inactive sites shall be inspected and maintained a minimum of once a month or within the 48 hours following a major storm event.

At no time shall more than one foot of sediment be allowed to accumulate within a trapped catch basin. All catch basins and conveyance lines shall be cleaned prior to paving. The cleaning operation shall not flush sediment laden water into the downstream system.

Stabilized construction entrances shall be installed at the beginning of construction and maintained for the duration of the project. Additional measures may be required to insure that all paved areas are kept clean for the duration of the project.

Appendix 7C - Background Information on Chemical Treatment

Coagulation and flocculation have been used for over a century to treat water. It is used less frequently for the treatment of wastewater. The use of coagulation and flocculation for treating stormwater is a very recent application. Experience with the treatment of water and wastewater has resulted in a basic understanding of the process, in particular factors that affect performance. This experience can provide insights as to how to most effectively design and operate similar systems in the treatment of stormwater.

Fine particles suspended in water give it a milky appearance, measured as turbidity. Their small size, often much less than 1 µm in diameter, give them a very large surface area relative to their volume. These fine particles typically carry a negative surface charge. Largely because of these two factors, small size and negative charge, these particles tend to stay in suspension for extended periods of time. Thus, removal is not practical by gravity settling. These are called stable suspensions. Polymers, as well as inorganic chemicals such as alum, speed the process of clarification. The added chemical destabilizes the suspension and causes the smaller particles to agglomerate. The process consists of three steps: coagulation, flocculation, and settling or clarification. Each step is explained below as well as the factors that affect the efficiency of the process.

<u>Coagulation:</u> Coagulation is the first step. It is the process by which negative charges on the fine particles that prevent their agglomeration are disrupted. Chemical addition is one method of destabilizing the suspension, and polymers are one class of chemicals that are generally effective. Chemicals that are used for this purpose are called coagulants. Coagulation is complete when the suspension is destabilized by the neutralization of the negative charges. Coagulants perform best when they are thoroughly and evenly dispersed under relatively intense mixing. This rapid mixing involves adding the coagulant in a manner that promotes rapid dispersion, followed by a short time period for destabilization of the particle suspension. The particles are still very small and are not readily separated by clarification until flocculation occurs.

<u>Flocculation:</u> Flocculation is the process by which fine particles that have been destabilized bind together to form larger particles that settle rapidly. Flocculation begins naturally following coagulation, but is enhanced by gentle mixing of the destabilized suspension. Gentle mixing helps to bring particles in contact with one another such that they bind and continually

grow to form "flocs." As the size of the flocs increases they become heavier and tend to settle more rapidly.

<u>Clarification:</u> The final step is the settling of the particles. Particle density, size and shape are important during settling. Dense, compact flocs settle more readily than less dense, fluffy flocs. Because of this, flocculation to form dense, compact flocs is particularly important during water treatment. Water temperature is important during settling. Both the density and viscosity of water are affected by temperature; these in turn affect settling. Cold temperatures increase viscosity and density, thus slowing down the rate at which the particles settle.

The conditions under which clarification is achieved can affect performance. Currents can affect settling. Currents can be produced by wind, by differences between the temperature of the incoming water and the water in the clarifier, and by flow conditions near the inlets and outlets. Quiescent water such as that which occurs during batch clarification provides a good environment for effective performance as many of these factors become less important in comparison to typical sedimentation basins. One source of currents that is likely important in batch systems is movement of the water leaving the clarifier unit. Given that flocs are relatively small and light the exit velocity of the water must be as low as possible. Sediment on the bottom of the basin can be resuspended and removed by fairly modest velocities.

<u>Coagulants:</u> Polymers are large organic molecules that are made up of subunits linked together in a chain-like structure. Attached to these chain-like structures are other groups that carry positive or negative charges, or have no charge. Polymers that carry groups with positive charges are called cationic, those with negative charges are called anionic, and those with no charge (neutral) are called nonionic.

Cationic polymers can be used as coagulants to destabilize negatively charged turbidity particles present in natural waters, wastewater and stormwater. Aluminum sulfate (alum) can also be used as this chemical becomes positively charged when dispersed in water. In practice, the only way to determine whether a polymer is effective for a specific application is to perform preliminary or on-site testing.

Polymers are available as powders, concentrated liquids, and emulsions (which appear as milky liquids). The latter are petroleum based, which are not allowed for construction stormwater treatment. Polymer effectiveness can degrade with time and also from other influences. Thus, manufacturers' recommendations for storage should be followed. Manufacturer’s recommendations usually do not provide assurance of water quality protection or safety to aquatic organisms. Consideration of water quality protection is necessary in the selection and use of all polymers.

Application Considerations: Application of coagulants at the appropriate concentration or dosage rate for optimum turbidity removal is important for management of chemical cost, for effective performance, and to avoid aquatic toxicity. The optimum dose in a given application depends on several site-specific features. Turbidity of untreated water can be important with turbidities greater than 5,000 NTU. The surface charge of particles to be removed is also important. Environmental factors that can influence dosage rate are water temperature, pH, and the presence of constituents that consume or otherwise affect polymer effectiveness. Laboratory experiments indicate that mixing previously settled sediment (floc sludge) with the untreated stormwater significantly improves clarification, therefore reducing the effective dosage rate. Preparation of working solutions and thorough dispersal of polymers in water to be treated is also important to establish the appropriate dosage rate.

For a given water sample, there is generally an optimum dosage rate that yields the lowest residual turbidity after settling. When dosage rates below this optimum value (underdosing) are applied, there is an insufficient quantity of coagulant to react with, and therefore destabilize, all of the turbidity present. The result is residual turbidity (after flocculation and settling) that is higher than with the optimum dose. Overdosing, application of dosage rates greater than the optimum value, can also negatively impact performance. Again, the result is higher residual turbidity than that with the optimum dose.

Mixing in Coagulation/Flocculation: The G-value, or just "G", is often used as a measure of the mixing intensity applied during coagulation and flocculation. The symbol G stands for “velocity gradient”, which is related in part to the degree of turbulence generated during mixing. High G-values mean high turbulence, and vice versa. High G-values provide the best conditions for coagulant addition. With high G's, turbulence is high and coagulants are rapidly dispersed to their appropriate concentrations for effective destabilization of particle suspensions.

Low G-values provide the best conditions for flocculation. Here, the goal is to promote formation of dense, compact flocs that will settle readily. Low G's provide low turbulence to promote particle collisions so that flocs can form. Low G's generate sufficient turbulence such that collisions are effective in floc formation, but do not break up flocs that have already formed.

Design engineers wishing to review more detailed presentations on this subject are referred to the following textbooks.

- Fair, G., J. Geyer and D. Okun, Water and Wastewater Engineering, Wiley and Sons, NY, 1968.

- American Water Works Association, Water Quality and Treatment, McGraw-Hill, NY, 1990.

- Weber, W.J., Physiochemical Processes for Water Quality Control, Wiley and Sons, NY, 1972.

<u>Polymer Batch Treatment Process Description:</u> Stormwater is collected at interception point(s) on the site and is diverted by gravity or by pumping to a storage pond or other holding area. The stormwater is stored until treatment occurs. It is important that the holding pond be large enough to provide adequate storage.

The first step in the treatment sequence is to check the pH of the stormwater in the storage pond. The pH is adjusted by the application of acid or base until the stormwater in the storage pond is within the desired pH range. When used, acid is added immediately downstream of the transfer pump. Typically sodium bicarbonate (baking soda) is used as a base, although other bases may be used. When needed, base is added directly to the storage pond. The stormwater is recirculated with the treatment pump to provide mixing in the storage pond. Initial pH adjustments should be based on daily bench tests. Further pH adjustments can be made at any point in the process.

Once the stormwater is within the desired pH range, the stormwater is pumped from the storage pond to a treatment cell as polymer is added. The polymer is added upstream of the pump to facilitate rapid mixing.

After polymer addition, the water is kept in a lined treatment cell for clarification of the sediment-floc. In a batch mode process, clarification typically takes from 30 minutes to several hours. Prior to discharge samples are withdrawn for analysis of pH and turbidity. If both are acceptable, the treated water is discharged.

Several configurations have been developed to withdraw treated water from the treatment cell. The original configuration is a device that withdraws the treated water from just beneath the water surface using a float with adjustable struts that prevent the float from settling on the cell bottom. This reduces the possibility of picking up sediment-floc from the bottom of the pond. The struts are usually set at a minimum clearance of about 12 inches; that is, the float will come within 12 inches of the bottom of the cell. Other systems have used vertical guides or cables which constrain the float, allowing it to drift up and down with the water level. More recent designs have an H-shaped array of pipes, set on the horizontal.

This scheme provides for withdrawal from four points rather than one. This configuration reduces the likelihood of sucking settled solids from the bottom. It also reduces the tendency for a vortex to form. Inlet diffusers, a long floating or fixed pipe with many small holes in it, are also an option.

Safety is a primary concern. Design should consider the hazards associated with operations, such as sampling. Facilities should be designed to reduce slip hazards and drowning. Tanks and ponds should have life rings, ladders, or steps extending from the bottom to the top.

Adjustment of the pH and Alkalinity: The pH must be in the proper range for the polymers to be effective, which is 6.5 to 8.5 for Calgon CatFloc 2953, the most commonly used polymer. As polymers tend to lower the pH, it is important that the stormwater have sufficient buffering capacity. Buffering capacity is a function of alkalinity. Without sufficient alkalinity, the application of the polymer may lower the pH to below 6.5. A pH below 6.5 not only reduces the effectiveness of the polymer, it may create a toxic condition for aquatic organisms. Stormwater may not be discharged without readjustment of the pH to above 6.5. The target pH should be within 0.2 standard units of the receiving water pH.

Experience gained at several projects in the City of Redmond has shown that the alkalinity needs to be at least 50 mg/L to prevent a drop in pH to below 6.5 when the polymer is added. Baking soda has been used to raise both the alkalinity and the pH. Although lime is less expensive than baking soda, if overdosed lime can raise the pH above 8.5 requiring downward adjustment for the polymer to be effective. Baking soda has the advantage of not raising the pH above 8.3 regardless of the amount that is added. Experience indicates that the amount of baking soda sufficient to raise the alkalinity to above 50 mg/L produces a pH near neutral or 7.

Alkalinity cannot be easily measured in the field. Therefore, conductivity, which can be measured directly with a hand-held probe, has been used to ascertain the buffering condition. It has been found through local experience that when the conductivity is above about 100 µS/cm the alkalinity is above 50 mg/L. This relationship may not be constant and therefore care must be taken to define the relationship for each site.

Experience has shown that the placement of concrete has a significant effect on the pH of construction stormwater. If the area of fresh exposed concrete surface is significant, the pH of the untreated stormwater may be considerably above 8.5. Concrete equipment washwater shall be controlled to prevent contact with stormwater. Acid may be added to lower the pH to the background level pH of the receiving water. The amount of acid needed to adjust the pH to the desired level is not constant but depends upon the polymer dosage, and the pH, turbidity, and alkalinity of the untreated stormwater. The acid commonly used is sulfuric although muriatic and ascorbic acids have been used. Pelletized dry ice has also been used and reduces the safety concerns associated with handling acid.

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Chapter 8 - Source Control

8.1 Introduction

8.1.1 Purpose

The purpose of this chapter is to provide guidance for selecting Best Management Practices (BMPs) to meet the Core Element #3 that "all known, available, and reasonable" source control BMPs shall be applied to all projects. This chapter can assist local governments and businesses to control urban sources of both conventional and toxic pollutants in stormwater. Application of the source control BMPs contained in this chapter can help attain state water quality standards to protect beneficial uses of receiving waters.

BMPs are schedules of activities, prohibitions of practices, maintenance procedures, and structural and(or) managerial practices, that when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State.

This chapter of the stormwater manual focuses on prevention of water-quality impacts from potential pollutant sources. Source control BMPs are structures or operations intended to prevent pollutants from coming into contact with stormwater through physical separation of areas or careful management of activities that are sources of pollutants. This chapter also identifies certain treatment BMPs that apply to specific types of pollutant sources.

8.1.2 Content and Organization of this Chapter

Chapter 8 of this Manual contains four sections and two appendices.

- Section 8.1 serves as an introduction and provides descriptions of operational and structural source control BMPs. It distinguishes between applicable (mandatory) BMPs and recommended BMPs. It describes the relationship between the source control BMPs in this chapter and regulatory requirements.
- Section 8.2 identifies stormwater pollutants and their adverse impacts.
- Section 8.3 presents operational BMPs that are applicable to commercial and industrial establishments.
    - Section 8.3.2 presents operational and structural BMPs designed to address specific types of pollutant sources. This chapter should be consulted to select specific BMPs for source control for inclusion in Stormwater Site Plans (see Chapter 3). The BMPs described in this chapter can also satisfy permit requirements under the National Pollutant Discharge Elimination System (NPDES). (Washington Department of Ecology, 1995).

- Section 8.4 presents structural BMPs that are applicable to commercial and industrial establishments
- Appendix 8A identifies pollutant generating sources at various land uses.
- Appendix 8B presents BMPs for managing street waste.

8.1.3 Operational and Structural Source Control BMPs

There are two categories of Source Control BMPs: operational and structural.

Operational Source Control BMPs are non-structural practices that prevent or reduce pollutants from entering stormwater. Examples include formation of a pollution prevention team, good housekeeping practices, preventive maintenance procedures, spill prevention and cleanup, employee training, inspections of pollutant sources, and record keeping. They can also include process changes, raw material/product changes, and recycling wastes.

Operational Source Control BMPs are considered the most cost-effective pollutant minimization practices.

Structural Source Control BMPs are physical, structural, or mechanical devices or facilities that are intended to prevent pollutants from entering stormwater. Examples of Structural Source Control BMPs typically include:

- Enclosing and(or) covering the pollutant source (e.g., within a building or other enclosure, a roof over storage and working areas, temporary tarp, etc.).
- Physically segregating the pollutant source to prevent run-on of uncontaminated stormwater.
- Devices that direct only contaminated stormwater to appropriate treatment BMPs (e.g., discharge to a sanitary sewer if allowed by the local jurisdiction).

8.1.4 Treatment BMPs for Specific Pollutant Sources

This chapter identifies specific treatment BMPs that apply to particular pollutant sources, such as fueling stations, railroad yards, storage and transfer of materials, etc. After identifying the applicable treatment BMPs, the reader can refer to Chapter 5 for design information.

Treatment BMPs include settling basins or vaults, oil/water separators, biofilters, wet ponds, infiltration systems, and emerging technologies such as media filtration. Treatment BMPs may be required by Ecology or local governments if a significant amount of a pollutant remains in the stormwater discharge after the application of operational and structural source control BMPs, or if the stormwater is discharged from a pollutant generating surface.

Ecology defines a "significant amount" as an amount of a pollutant in a stormwater discharge that is amenable to available and reasonable methods of prevention and treatment; or an amount of a pollutant that has a reasonable potential to cause a violation of surface or ground water quality, or sediment management standards. Refer to Chapter 5 for expected performance criteria of treatment BMPs.

To provide guidance for significant amount determinations and performance goals, Ecology's 1995 industrial stormwater general permit refers to the use of maximum discharge targets for the following stormwater pollutants:

- Oil and grease: a maximum 24-hour average concentration (or during a calendar day) of 10 mg/L, or a grab sample maximum concentration of 15 mg/L at any time, and no ongoing or frequently recurring visible sheen in the stormwater discharge.
- Settleable solids: a maximum 0.1 ml/L (grab sample) based on an analytical procedure using a one-hour settling time.
- pH: between 6.0 and 9.0 (grab sample).
- Other pollutants, particularly heavy metals and other toxics, must also be considered when identifying pollutants at a facility.

Discharge targets are not mandatory effluent limits, and discharging below target levels does not necessarily guarantee compliance with water quality standards. Local jurisdictions may implement more stringent requirements for total suspended solids and total petroleum hydrocarbons (TPH).

8.1.5 Distinction between Applicable and Recommended BMPs

This chapter uses the terminology "applicable BMPs" and "recommended BMPs" to address an important distinction. This section explains the use of these terms.

Applicable BMPs

The NPDES General Stormwater Permits for municipal, industrial and construction stormwater discharges require the adoption or use of Ecology's stormwater manual or an equivalent manual. BMPs identified in this chapter, as applicable, must be included in local government manuals to be considered equivalent to Ecology's stormwater manual. Ecology expects local governments to require those BMPs described as applicable at new development and redevelopment sites. The applicable BMPs will also be required if they are incorporated into NPDES permits, or if they are included by local governments in a stormwater program for existing facilities. The applicable BMPs in this chapter may also be required by other regulatory programs such as the State Environmental

Policy Act (SEPA), water quality certification under Section 401 of the Clean Water Act, and Hydraulic Project Approvals (HPAs).

Recommended BMPs

This chapter also contains recommended BMPs. These are not expected to be mandatory, but are offered as approaches that go beyond or complement the minimum applicable BMPs. Implementing the recommended BMPs may improve control of pollutants and provide a more comprehensive and environmentally effective stormwater management program.

8.2 Stormwater Pollutants and Their Adverse Impact

The stormwater pollutants of most concern are total suspended solids (TSS), oil and grease, nutrients, pesticides, other organics, pathogens, biochemical oxygen demand (BOD), heavy metals, and salts (chlorides) (USEPA, 1995, Field and Pitt, 1997, Strecker, et.al., 1997).

Total Suspended Solids

This represents particulate solids such as eroded soil, heavy metal precipitates, and biological solids (all considered as conventional pollutants), which can cause sedimentation in streams and turbidity in receiving surface waters. These sediments can destroy the desired habitat for fish and can impact drinking water supplies. The sediment may be carried to streams, lakes, or other receiving waters where they may be toxic to aquatic life and make dredging necessary.

Oil and Grease

Oil and grease can be toxic to aquatic life. Concentrations in stormwater from commercial and industrial areas often exceed the Washington Department of Ecology (Ecology) guidelines of: 10 mg/l maximum daily average, 15 mg/L maximum at any time, and no ongoing or frequently recurring visible sheen.

Nutrients

Phosphorus and nitrogen compounds can cause excessive growth of aquatic vegetation in lakes and marine waters.

BOD

This represents organic, nitrogenous and other materials that are consumed by bacteria present in receiving waters. Oxygen may be depleted in the process, threatening higher organisms such as fish.

Toxic Organics

A study found 19 of the U.S. Environmental Protection Agency’s 121 priority pollutants present in the runoff from Seattle streets. The most frequently detected pollutants were pesticides, phenols, phthalates, and polynuclear aromatic hydrocarbons (PAHs).

Heavy Metals

Stormwater can contain heavy metals such as lead, zinc, cadmium, and copper at concentrations that often exceed water quality criteria and that can be toxic to fish and other aquatic life. Research in Puget Sound has shown that metals and toxic organics concentrate in sediments and at the water surface (microlayer) where they interfere with the reproductive cycle of many biotic species, and cause tumors and lesions in fish.

pH

A measure of the alkalinity or acidity which can be toxic to fish if it varies appreciably from neutral pH of 7.0.

Bacteria and Viruses

Stormwater can contain disease-causing bacteria and viruses, although not at concentrations found in sanitary sewage. Shellfish subjected to stormwater discharges near urban areas are usually unsafe for human consumption. Research has shown that the concentrations of pollutants in stormwater from residential, commercial, and industrial areas can exceed Ecology's water quality standards and guidelines. See table below.

	CONCENTRATIONS (µg/l or ppb)							ECOLOGY/USEPA CRITERIA [D]			
Pollutant/ Criteria	**Commercial**		**Industrial**		**Residential**		**Highway[C]**	**Freshwater Acute**	**Freshwater Chronic**	**Saltwater Acute**	**Saltwater Chronic**
	(A)	(B)	(A)	(B)	(A)	(B)					
Total Phosphorus	210	260	380	680	150	260	113-790	--	--	--	--
Tot. Copper	22	31	32	49	10	31	12-152	9	7	2.9	--
Tot. Lead	26	37	21	121	10	37	19-36	34	1.3	220	8.5
Tot. Zinc	115	200	251	1,324	69	200	56-638	65	59	95	86
TSS, mg/L	55	66	93	134	43	66	63-798	--	--	--	--
BOD, mg/L	7.4	8	18	12	5.8	8	12.7-111	--	--	--	--
Oil, mg/L	--		--		--		8.9-27	--	--	--	--
Fecal Coliform	980 orgs/ 100 mls		--		--		--	50 colonies/ 100 mls[E]	--	--	--

A. Eric Strecker, “Analysis of Oregon Urban Runoff Water Quality Data Collected from 1990 to 1996”- 2/1997 Report

B. Santa Clara-1990: median data

C. WSDOT Stormwater Management Plan, 3/25/97, WA. and Oregon data

D. Dissolved metal criteria in freshwater at a hardness of 50 ppm (Chapter 173-201A WAC), saltwater criteria expressed as a function of water effect ratio (40 CFR Part 131)

E. Ecology geometric mean criterion for class AA waters

8.3 Selection of Operational and Structural Source Control BMPs

Urban stormwater pollutant sources include manufacturing and commercial areas; high use vehicle parking lots; material (including wastes) storage and handling; vehicle/equipment fueling, washing, maintenance, and repair areas; erodible soil; streets and highways; and the handling and application of deicers and lawn care products.

Reduction or the elimination of stormwater pollutants can be achieved by implementing "operational source control BMPs," including good housekeeping, employee training, spill prevention and cleanup, preventive maintenance, regular inspections, and record keeping. These BMPs can be combined with impervious containments and covers, i.e., structural source control BMPs. If operational and structural source control BMPs are not feasible or adequate, then stormwater treatment BMPs will be necessary. Selecting cost-effective BMPs should be based on an assessment of the pollutants and their sources.

The applicable BMPs described in this section, or equivalent BMPs, will help businesses comply with Ecology's Stormwater General Permit requirements which apply to new and existing facilities. For new developments or redevelopments not covered under that permit, implementation of those BMPs that are specified as applicable BMPs in this Manual, or equivalent BMPs, will also be required if incorporated into local government ordinances or equivalent documents. Facilities that are not required to apply the applicable and recommended BMPs described in this chapter are encouraged to implement them.

The selection of source control BMPs described in this section should be based on land use and the pollutant generating sources. Appendix 8A describes various land uses and activities, and the potential pollutant generating sources associated with those activities. For example, if a commercial printing business conducts vehicle maintenance, weed control with herbicides, loading and unloading of materials, and vehicle washing, it should refer to the following BMP sections for these activities: Maintenance and Repair of Vehicles and Equipment; Landscaping and Lawn/Vegetation Management; Loading and Unloading Areas for Liquid or Solid Material; Washing and Steam Cleaning Vehicle/Equipment/ Building Structures; and Commercial Printing Operations.

The entire operational BMP section of this chapter must be reviewed for applicability. The BMPs described herein may also be applicable for land uses not listed in Appendix 8A.

8.3.1 Applicable Operational Source Control BMPs

The following operational source control BMPs must be implemented at the commercial and industrial establishments listed in Appendix 8A, where required by Ecology's Industrial General Permit or by local government ordinances.

- Promptly contain and clean up solid and liquid pollutant leaks and spills, including oils, solvents, fuels, and dust from manufacturing operations on any exposed soil, vegetation, or paved area.
- Sweep paved material handling and storage areas regularly, as needed, for the collection and disposal of dust and debris that could contaminate stormwater. Do not hose down pollutants from any area to the ground, storm drain, conveyance ditch, or receiving water unless necessary for dust control purposes to meet air quality regulations, and unless the pollutants are conveyed to a treatment system approved by the local jurisdiction.
- Clean oils, debris, sludge, etc. from all BMP systems regularly, including catch basins, settling/detention basins, oil/water separators, boomed areas, and conveyance systems, to prevent the contamination of stormwater. The following paragraph provides references to assist in determining if a waste must be handled as hazardous waste.

Ecology requirements for generators of dangerous wastes

The state's Dangerous Waste Regulations (Chapter 173-303 WAC) cover accumulation, storage, transportation, treatment and disposal of dangerous wastes. Of interest to this manual are those businesses or public agencies that accumulate the waste at their building until taken from the site by a contract hauler. For more information on applicable requirements for hazardous wastes, see "Step by Step: Fact Sheets for Hazardous Waste Generators," publication #91-12, available from Ecology's regional offices.

- Promptly repair or replace all substantially cracked or otherwise damaged paved secondary containment, high-intensity parking, and any other drainage areas that are subjected to pollutant material leaks or spills.
- Promptly repair or replace all leaking connections, pipes, hoses, valves, etc. that can contaminate stormwater.

The following are recommended additional good housekeeping BMPs:

- Clean up pollutant liquid leaks and spills in impervious uncovered containment areas at the end of each working day.
- Use solid absorbents, e.g., clay and peat absorbents and rags for cleanup of liquid spills/leaks, where practicable.
- Recycle materials, such as oils, solvents, and wood waste, to the maximum extent practicable.

Preventive Maintenance

- Prevent the discharge of unpermitted liquid or solid wastes, process wastewater, and sewage to ground or surface water, or to storm drains that discharge to surface water, or to the ground.
- Do not connect floor drains in potential pollutant source areas to storm drains, surface water, or to the ground.
- Conduct all oily parts cleaning, steam cleaning, or pressure washing of equipment or containers inside a building, or on an impervious contained area, such as a concrete pad. Direct contaminated stormwater from such an area to a sanitary sewer where allowed by local jurisdiction, or to other approved treatment.
- Do not pave over contaminated soil unless it has been determined that groundwater has not been and will not be contaminated by the soil. Call Ecology for assistance.
- Construct impervious areas that are compatible with the materials handled. Portland cement concrete, asphalt, or equivalent material may be considered.
- Use drip pans to collect leaks and spills from industrial/commercial equipment, such as log stackers, industrial parts, trucks, and other vehicles stored outside.
- At industrial and commercial facilities, drain oil and fuel filters before disposal. Discard empty oil and fuel filters, oily rags and other oily solid waste into appropriately closed and properly labeled containers, and in compliance with the Uniform Fire Code.
- For the storage of liquids use containers, such as steel and plastic drums, that are rigid and durable, corrosion resistant to the weather and fluid content, non-absorbent, water tight, rodent-proof, and equipped with a close fitting cover.
- For the temporary storage of solid wastes contaminated with liquids or other potential pollutant materials use dumpsters, garbage cans, drums and comparable containers, that are durable, corrosion resistant, non-absorbent, non-leaking, and equipped with either a solid cover or screen cover to prevent littering. If covered with a screen, the container must be stored under a lean-to or equivalent structure.
- Where exposed to stormwater, use containers, piping, tubing, pumps, fittings, and valves that are appropriate for their intended use and for the contained liquid.

The following are recommended additional preventive maintenance BMPs:

- Where feasible, store potential stormwater pollutant materials inside a building or under a cover, and(or) containment.

- Minimize use of toxic cleaning solvents, such as chlorinated solvents, and other toxic chemicals.
- Use environmentally safer raw materials, products, additives, etc., such as substitutes for zinc used in rubber production.
- Recycle waste materials, such as solvents, coolants, oils, degreasers, and batteries to the maximum extent feasible.
- Empty drip pans immediately after a spill or leak is collected in an uncovered area.
- Stencil warning signs at stormwater catch basins and drains, e.g., "Dump no waste."

***Note**: Evidence of stormwater contamination can include the presence of visible sheen, color, or turbidity in the runoff; or present or historical operational problems at the facility. Simple pH measurements with litmus or pH paper can be used to test for stormwater contamination in areas subject to acid or alkaline contamination.*

Spill Prevention and Cleanup

- Immediately upon discovery: stop, contain, and clean up all spills.
- If pollutant materials are stored on-site, have spill containment and cleanup kits readily accessible.
- If the spill has reached or may reach a sanitary or a storm sewer, groundwater, or surface water, notify Ecology and the local jurisdiction immediately. Notification must comply with and federal spill reporting requirements. (See also record keeping at the end of this section and BMPs for Spills of Oil and Hazardous Substances.)
- Do not flush absorbent materials or other spill cleanup materials to a storm drain. Collect the contaminated absorbent material as a solid and place in appropriate disposal containers.

The following is a recommended additional BMP:

- Place and maintain emergency spill containment and cleanup kit(s) at outside areas where there is a potential for fluid spills. These kits should be appropriate for the materials being handled and the size of the potential spill.

***Note**: Ecology recommends that the kit(s) include: salvage drums or containers, such as high density polyethylene, polypropylene or polyethylene sheet-lined steel; polyethylene or equivalent disposal bags; an emergency response guidebook; safety gloves/clothes/equipment; shovels or other soil removal equipment; and oil containment booms and absorbent pads; all stored in an impervious container.*

Employee Training

Train all employees that work in pollutant source areas in identifying pollutant sources and in understanding pollutant control measures, spill response procedures, and environmentally acceptable material handling practices - particularly those related to vehicle/equipment liquids, such as fuels, and vehicle/equipment cleaning. Use Ecology's "Stormwater Pollution Prevention Planning for Industrial Facilities" (WQ-R-93-015, 9/93) as a training reference.

Inspections

At a minimum during normal or dry weather years, conduct two visual inspections each year, one inspection during October 1-April 30, and the other during May 1-September 30, as follows:

- Verify that the descriptions of the pollutant sources identified in the stormwater pollution control program are accurate.
- Verify that the stormwater pollutant controls (BMPs) being implemented are adequate.
- Include observations of the presence of floating materials, suspended solids, oil and grease, discoloration, turbidity and odor in the stormwater discharges; in outside vehicle maintenance/repair areas; and in liquid handling and storage areas. In areas where acid or alkaline materials are handled or stored, use a simple litmus or pH paper to identify those types of stormwater contaminants.
- Determine whether there are unpermitted non-stormwater discharges to storm drains or receiving waters, such as process wastewater and vehicle/equipment wash water; and either eliminate or obtain a permit for such a discharge.

Recordkeeping

Retain the following reports for three years:

- Visual inspection reports which should include: scope of the inspection, the personnel conducting the inspection, the date(s) of the inspection, major observations relating to the implementation of the SWPPP (performance of the BMPs, etc.) and actions taken to correct BMP inadequacies.
- Reports on spills of oil or hazardous substances in greater than Reportable Quantities (Code of Federal Regulations Title 40 Parts 302.4 and 117), including the following: oil, gasoline, or diesel fuel, that causes a violation of the state's water quality standards, or causes a film or sheen upon or discoloration of the waters of the state or adjoining shorelines, or causes a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines.

- To report a spill or to determine if a spill is a substance of a reportable quantity, call your Ecology regional office and ask for an oil spill operations or a hazardous waste specialist:

Eastern Region	(509) 456-2926
Central Region	(509) 575-2490

  Also refer to Emergency Spill Response in Washington State, Publication #97-1165-CP.

The following is additional recommended record keeping:

- Maintain records of all related pollutant control and pollutant generating activities, such as training, materials purchased, material use and disposal, maintenance performed, etc.

8.3.2 Pollutant Source-Specific BMPs

The source-specific BMPs described in this section, or equivalent BMPs, can be applied to control the sources of pollutants identified in Appendix 8A.

BMPs for the Building, Repair, and Maintenance of Boats and Ships

Description of Pollutant Sources: Sources of pollutants at boat and shipbuilding, repair, and maintenance at boatyards, shipyards, ports, and marinas include pressure washing, surface preparation, paint removal, sanding, painting, engine maintenance and repairs, and material handling and storage, if conducted outdoors. Potential pollutants include: spent abrasive grits, solvents, oils, ethylene glycol, wash water, paint over-spray, cleaners/detergents, anti-corrosive compounds, paint chips, scrap metal, welding rods, resins, glass fibers, dust, and miscellaneous trash. Pollutant constituents include TSS, oil and grease, organics, copper, lead, tin, and zinc.

Pollutant Control Approach: Apply good housekeeping, preventive maintenance, and cover and contain BMPs in and around work areas.

Applicable Operational BMPs: All boatyards in Washington State with haul out facilities are required to be covered under the NPDES General Permit for Boatyard Activities. All shipyards in Washington State with haul out facilities such as drydocks, graving docks, marine railways or synchrolifts are required to be covered under an individual NPDES Permit. Any facility conducting boatyard or shipyard activities strictly from dockside, with no vessel haul out, must be covered by the NPDES General Stormwater Permit for Industrial Activities. The applicable operational BMPs are:

- Clean regularly all accessible work, service and storage areas to remove debris, spent sandblasting material, and any other potential stormwater pollutants.
- Sweep rather than hose debris on the dock. If hosing is unavoidable,

the hose water must be collected and conveyed to treatment.

- Collect spent abrasives regularly and store under cover to await proper disposal.
- Dispose of greasy rags, oil filters, air filters, batteries, spent coolant, and degreasers properly.
- Drain oil filters before disposal or recycling.
- Immediately repair or replace leaking connections, valves, pipes, hoses, and equipment that causes the contamination of stormwater.
- Use drip pans, drop cloths, tarpaulins, or other protective devices in all paint mixing and solvent operations, unless carried out in impervious contained and covered areas.
- Convey sanitary sewage to pump-out stations, portable on-site pump-outs, or commercial mobile pump-out facilities or other appropriate onshore facilities.
- Maintain automatic bilge pumps in a manner that will prevent waste material from being pumped automatically into surface water.
- Prohibit uncontained spray painting, blasting, or sanding activities over open water.
- Do not dump or pour waste materials down floor drains, sinks, or outdoor storm drain inlets that discharge to surface water. Plug floor drains that are connected to storm drains or to surface water. If necessary, install a sump that is pumped regularly.
- Prohibit outside spray painting, blasting, or sanding activities during windy conditions that render containment ineffective.
- Do not burn paint and(or) use spray guns on topsides or above decks.
- Immediately clean up any spillage on dock, boat, or ship deck areas and dispose of the wastes properly.
- In the event of an accidental discharge of oil or hazardous material into waters of the state or onto land with a potential for entry into state waters, immediately notify the yard, port, or marina owner or manager, the Department of Ecology, and the National Response Center at 1-800-424-8802 (24-hour). If the spill can reach or has reached marine water, call the U.S. Coast Guard at (206) 217-6232.

Applicable Structural Source Control BMPs:

- Use fixed platforms with appropriate plastic or tarpaulin barriers as work surfaces and for containment when work is performed on a vessel in the water to prevent blast material or paint overspray from contacting stormwater or the receiving water. Use of such platforms will be kept to a minimum and at no time be used for extensive repair or construction (anything in excess of 25 percent of the surface area of the vessel above the waterline).

- Use plastic or tarpaulin barriers beneath the hull and between the hull and dry dock walls to contain and collect waste and spent materials. Clean and sweep regularly to remove debris.
- Enclose, cover, or contain blasting and sanding activities to the maximum extent practicable to prevent abrasives, dust, and paint chips, from reaching storm sewers or receiving water. Use plywood and(or) plastic sheeting to cover open areas between decks when sandblasting (scuppers, railings, freeing ports, ladders, and doorways).
- Direct deck drainage to a collection system sump for settling and(or) additional treatment.
- Store cracked batteries in a covered secondary container.
- Apply source control BMPs given in this chapter for other activities conducted at the marina, boat yard, shipyard, or port facility (BMPs for Fueling at Dedicated Stations, BMPs for Washing and Steam Cleaning Vehicle/Equipment/Building Structures, and BMPs for Spills of Oil and Hazardous Substances).

Recommended Additional Operational BMPs: The following BMPs are recommended, unless they are required under a NPDES or Washington State Waste Discharge Permit:

- Consider recycling paint, paint thinner, solvents, used oils, oil filters, pressure wash wastewater, and any other recyclable materials.
- Perform paint and solvent mixing, fuel mixing, etc. on shore.

BMPs for Commercial Animal Handling Areas

Description of Pollutant Sources: Animals at racetracks, kennels, fenced pens, veterinaries, and businesses that provide boarding services for horses, dogs, cats, etc. can generate pollutants from the following activities: manure deposits, animal washing, grazing, and any other animal handling activity that could contaminate stormwater. Pollutants can include coliform bacteria, nutrients, and total suspended solids.

Pollutant Control Approach: To prevent, to the maximum extent practicable, the discharge of contaminated stormwater from animal handling and keeping areas.

Applicable Operational BMPs:

- Regularly sweep and clean animal keeping areas to collect and properly dispose of droppings, uneaten food, and other potential stormwater contaminants.
- Do not hose down to storm drains or to receiving water those areas that contain potential stormwater contaminants.

- Do not allow any wash waters to be discharged to storm drains or to receiving water without proper treatment.
- If animals are kept in unpaved and uncovered areas, the ground must either have vegetative cover or some other type of ground cover, such as mulch.
- If animals are not leashed or in cages, the area where animals are kept must be surrounded by a fence or other means that prevents animals from moving away from the controlled area where BMPs are used.

BMPs for Commercial Composting

Description of Pollutant Sources: Commercial compost facilities, operating outside without cover, require large areas to decompose wastes and other feedstocks. These facilities should be designed to separate stormwater from leachate (i.e., industrial wastewater) to the greatest extent possible. When stormwater is allowed to contact any active composting areas, including waste receiving and processing areas, it becomes leachate. Pollutants in leachate include: nutrients, biochemical oxygen demand (BOD), organics, coliform bacteria, acidic pH, color, and suspended solids. Stormwater at a compost facility consists of runoff from areas not associated with active processing and curing, such as: product storage areas, vehicle maintenance areas, and access roads.

NPDES Permit Requirements: Discharge of leachate from a compost facility will require a state waste discharge or NPDES permit from Ecology, depending on the disposal method chosen for managing leachate at the facility. (See Chapter 2 in "Compost Facility Resource Handbook, Guidance for Washington State," Publication # 97-502, November 1998.) An additional alternative, zero discharge, is possible by containing all leachate from the facility (in tanks or ponds) or preventing production of leachate (by composting under a roof or in an enclosed building).

Pollutant Control Approach: Consider the leachate control specified in publication #97-502 or zero leachate discharge.

Applicable Operational BMPs:

- Ensure that the compost feedstocks do not contain dangerous wastes, regulated under Chapter 173-303 WAC, or hazardous products of a similar nature, or solid wastes not beneficial to the composting process. Employees must be trained to screen for these materials in incoming wastes.
- Contact other federal, state, and local agencies with environmental or zoning authority for applicable permit and regulatory information. Local health departments are responsible for issuing solid waste handling permits for commercial compost facilities.
- Apply for coverage under the General Permit to Discharge Stormwater Associated with Industrial Activities, if the facility discharges stormwater to surface water or a municipal stormwater system. If all

stormwater from the facility infiltrates into the surrounding area, the general permit is not required.

- Develop a plan of operations as outlined in the “Compost Facility Resource Handbook,” Publication #97-502, November 1998.
- Store finished compost in a manner to prevent contamination of stormwater.

Applicable Structural Source Control BMPs:

- Refer to “Compost Facility Resource Handbook, Guidance for Washington State,” Publication # 97-502, November 1998, for additional design criteria and information.
- Compost pads are required for all uncovered facilities in areas of the state with wet climates (per water quality regulations).
- Provide curbing for all compost pads to prevent stormwater run-on and leachate run-off.
- Slope all compost pads sufficiently to direct leachate to the collection device.
- Provide one or more sumps or catch basins capable of collecting all leachate generated by the design storm and conveying it to the leachate holding structure for all compost pads.

Applicable Treatment BMPs:

- Convey all leachate from composting operations to a sanitary sewer, holding tank, or on-site treatment systems designed to treat the leachate and TSS.
- Ponds used to collect, store, or treat leachate and other contaminated waters associated with the composting process must be lined to prevent groundwater contamination. Apply “AKART” or All Known Available and Reasonable Methods of Prevention and Treatment to all pond liners, regardless of the construction materials.

Recommended Additional BMPs:

- Clean up debris from yard areas regularly.
- Locate stored residues in areas designed to collect leachate.
- Limit storage times of residues to prevent degradation and generation of leachate.
- Consider using leachate as make-up water in early stages of the composting process. Since leachate can contain pathogenic bacteria, care should be taken to avoid contaminating finished product or nearly finished product with leachate.

- In areas of the state with dry climates, consider using evaporation as a means of reducing the quantity of leachate.

BMPs for Commercial Printing Operations

Description of Pollutant Sources: Materials used in the printing process include: inorganic and organic acids, resins, solvents, polyester film, developers, alcohol, vinyl lacquer, dyes, acetates, and polymers. Waste products may include: waste inks and ink sludge, resins, photographic chemicals, solvents, acid and alkaline solutions, chlorides, chromium, zinc, lead, spent formaldehyde, silver, plasticizers, and used lubricating oils. As the printing operations are conducted indoors, the only likely points of potential contact with stormwater are the outside temporary storage of waste materials and offloading of chemicals at external unloading bays. Pollutants can include TSS, pH, heavy metals, oil and grease, and chemical oxygen demand (COD).

Pollutant Control Approach: Ensure appropriate disposal and NPDES permitting of process wastes. Cover and contain stored raw and waste materials.

Applicable Operational BMPs:

- Discharge process wastewaters to a sanitary sewer, if approved by the local jurisdiction, or to an approved process wastewater treatment system.
- Do not discharge process wastes or wastewaters into storm drains or surface water.
- Determine whether any of these wastes qualify for regulation as dangerous wastes and dispose of them accordingly.

Applicable Structural Source Control BMP: Store raw materials or waste materials that could contaminate stormwater in covered and contained areas.

Recommended Additional BMPs:

- Train all employees in pollution prevention, spill response, and environmentally acceptable materials handling procedures.
- Store materials in proper, appropriately labeled containers. Identify and label all chemical substances.
- All stormwater management devices should be inspected regularly and maintained as necessary.
- Try to use press washes without listed solvents, and with the lowest possible volatile organic compound (VOC) content. Do not evaporate ink cleanup trays to the outside atmosphere.
- Place cleanup sludges into a container with a tight lid and dispose of as hazardous waste. Do not dispose of cleanup sludges in the garbage or in containers of soiled towels.

For additional information on pollution prevention, the following Washington Department of Ecology publications are recommended: “A Guide for Screen Printers,” Publication #94-137 and “A Guide for Lithographic Printers,” Publication #94-139.

BMPs for Deicing and Anti-Icing Operations (Airports and Streets)

Description of Pollutant Sources: Deicing and(or) anti-icing compounds are used on highways, streets, airport runways, and on aircraft to control ice and snow. Typically ethylene glycol and propylene glycol are deicers used on aircraft. Deicers commonly used on highways and streets include: calcium magnesium acetate (CMA), calcium chloride, magnesium chloride, sodium chloride, urea, and potassium acetate. The deicing and anti-icing compounds become pollutants when they are conveyed to storm drains or to surface water after application. Leaks and spills of these chemicals can also occur during their handling and storage.

Applicable BMPs for Streets and Highways:

- Select de and anti-icers that cause the least adverse environmental impact. Apply only as needed using minimum quantities.
- Where feasible and practicable use roadway deicers, such as calcium magnesium acetate, potassium acetate, or similar materials, that cause less adverse environmental impact than urea and sodium chloride.
- Store and transfer de/anti-icing materials on an impervious containment pad in accordance with BMP Storage or Transfer (Outside) of Solid Raw Materials, By-Products, or Finished Products in this document.
- Sweep/clean up accumulated de/anti-icing materials and grit from roads as soon as practicable after the road surface clears.

Recommended Additional BMPs:

- Intensify roadway cleaning in early spring to help remove particulates from road surfaces.
- Include limits on toxic metals in the specifications for de/anti-icers.

BMPs for Airport Deicing and Anti-Icing Operations

Note: *EPA is currently studying airport deicing as part of the pretreatment regulations (40 CFR 403). These regulations are not expected to be promulgated for several years.*

Pollutant Control Approach for Aircraft: Spent glycol discharges in aircraft application areas are process wastewaters that are regulated under Ecology’s industrial stormwater general permit. (Contact the Ecology regional office for details.) BMPs for aircraft de/anti-icers must be consistent with aviation safety and the operational needs of the aircraft operator.

Applicable BMPs for Aircraft:

- Conduct aircraft deicing or anti-icing applications in impervious containment areas. Collect aircraft deicer or anti-icer spent chemicals, such as glycol, draining from aircraft in deicing or anti-icing application areas. Convey the spent chemicals, in accordance with an adopted plan approved by agencies with jurisdiction, to a sanitary sewer, treatment facility, or other disposal or recovery facility consistent with the plan. Divert deicing runoff from paved gate areas to appropriate collection areas or conveyances for proper treatment or disposal.

- Do not allow spent deicer or anti-icer chemicals or stormwater contaminated with aircraft deicer or anti-icer chemicals to be discharged from application areas, including gate areas, to surface water, or groundwater, directly or indirectly.
- Transfer deicing and anti-icing chemicals on an impervious containment pad, or equivalent spill/leak containment area, and store in secondary containment areas. (See Storage of Liquids in Above-Ground Tanks).

Recommended Additional BMPs for Aircraft:

- Establish a centralized aircraft de/anti-icing facility, if feasible and practicable, or in designated areas of the tarmac equipped with separate collection drains for the spent deicer liquids.
- Consider installing an aircraft de/anti-icing chemical recovery system, if practicable, or contract with a chemical recycler.

Note: *Be aware of the applicable containment BMP of aircraft de/anti-icing applications, and applicable treatment BMPs for de/anti-icer spent chemicals such as glycols.*

Applicable BMPs for Airport Runways/Taxiways:

- Avoid excessive application of all de/anti-icing chemicals, to prevent contamination of stormwater.
- Store and transfer de/anti-icing materials on an impervious containment pad or an equivalent containment area and(or) under cover in accordance with “BMP Storage or Transfer (Outside) of Solid Raw Materials, By-Products, or Finished Products” in this document. Other material storage and transfer approaches may be considered if it can be demonstrated that stormwater will not be contaminated, or that the de/anti-icer material cannot reach surface or ground waters.

Recommended Additional BMPs for Airport Runways/Taxiways:

- Include limits on toxic materials and phosphorous in the specifications for de/anti-icers, where applicable.
- Consider using anti-icing materials rather than deicers if it will result in less adverse environmental impact.

- Select cost-effective de/anti-icers that cause the least adverse environmental impact.

BMPs for Dust Control at Disturbed Land Areas and Unpaved Roadways and Parking Lots

Note: *Contact the local Air Quality Authority for appropriate and required BMPs for dust control to implement at your project site.*

Description of Pollutant Sources: Dust can cause air and water pollution problems, particularly at demolition sites and in arid areas where reduced rainfall exposes soil particles to transport by air.

Pollutant Control Approach: Minimize dust generation and apply environmentally friendly and government approved dust suppressant chemicals, if necessary.

Applicable Operational BMPs:

- Sprinkle or wet down soil or dust with water as long as it does not result in a wastewater discharge.
- Use only local and(or) state government approved dust suppressant chemicals such as those listed in Ecology Publication #96-433, “Techniques for Dust Prevention and Suppression.”
- Avoid excessive and repeated applications of dust suppressant chemicals. Time the application of dust suppressants to avoid or minimize their wash-off by rainfall or human activity, such as irrigation.
- Apply stormwater containment to prevent the conveyance of stormwater TSS into storm drains or receiving waters.
- The use of motor oil for dust control is prohibited. Care should be taken when using lignin derivatives and other high BOD chemicals in excavations or areas easily accessible to surface water or groundwater.
- Consult with the Ecology regional office in your area on discharge permit requirements, if the dust suppression process results in a wastewater discharge to the ground, groundwater, storm drain, or surface water.

Recommended Additional Operational BMPs for Roadways and Other Trafficked Areas:

- Consider limiting use of off-road recreational vehicles on dust generating land.
- Consider paving unpaved permanent roads and other trafficked areas at municipal, commercial, and industrial areas.
- Consider paving or stabilizing shoulders of paved roads with gravel, vegetation, or local government approved chemicals.
- Encourage use of alternate paved routes, if available.
- Vacuum or wet sweep fine dirt and skid control materials from paved

roads soon after winter weather ends or when needed.

- Consider using traction sand that is pre-washed to reduce dust emissions.

Additional Recommended Operational BMPs for Dust Generating Areas:

- Prepare a dust control plan. Helpful references include: "Control of Open Fugitive Dust Sources" (EPA-450/3-88-088), and "Fugitive Dust Background Document and Technical Information Document for Best Available Control Measures" (EPA-450/2-92-004).
- Limit exposure of soil (dust source) as much as feasible.
- Stabilize dust-generating soil by growing and maintaining vegetation, mulching, topsoiling, and(or) applying stone, sand, or gravel.
- Apply windbreaks in the soil, such as trees, board fences, tarp curtains, bales of hay, etc.
- Cover dust-generating piles with wind-impervious fabric or equivalent material.

__Note__: Contact the local Air Quality Authority for appropriate and required BMPs for dust control to implement at your project site.

BMPs for Dust Control at Manufacturing Areas

Description of Pollutant Sources: Industrial material handling activities can generate considerable amounts of dust that is typically removed using exhaust systems. This can generate air emissions that can contaminate stormwater. Dusts can be generated at cement and concrete products mixing, and wherever powdered materials are handled. Particulate materials that are of concern to air pollution control agencies include grain dust, sawdust, coal, gravel, crushed rock, cement, and boiler fly ash. The objective of this BMP is to reduce the stormwater pollutants caused by dust generation and control.

Pollutant Control Approach: Prevent dust generation and emissions, where feasible, regularly clean-up dust that can contaminate stormwater, and convey dust contaminated stormwater to proper treatment.

Applicable BMPs:

- Clean, as needed, powder material handling equipment and vehicles that can be sources of stormwater pollutants, to remove accumulated dust and residue.
- Regularly sweep dust accumulation areas that can contaminate stormwater. Sweeping should be conducted using vacuum filter equipment to minimize dust generation and to ensure optimal dust removal.

Recommended BMPs:

- In manufacturing operations, train employees to carefully handle powders to prevent generation of dust.
- Use dust filtration/collection systems, such as bag house filters, cyclone separators, etc. to control vented dust emissions that could contaminate stormwater. Control of zinc dusts in rubber production is one example.
- Use water spray to flush dust accumulations to sanitary sewers where allowed by the local jurisdiction or to another appropriate treatment system.
- Use approved dust suppressants such as those listed in Ecology Publication “Techniques for Dust Prevention and Suppression,” Ecology publication #96-433, 1996. Application of some products may not be appropriate in close proximity to receiving waters or conveyances close to receiving waters. For more information check with the Ecology regional office or the local jurisdiction.

Recommended Treatment BMPs: For removal of TSS in stormwater use sedimentation basins, wet ponds, wet vaults, catch basin filters, vegetated filter strips, or equivalent sediment removal BMPs.

BMPs for Fueling at Dedicated Stations

Description of Pollutant Sources: A fueling station is a facility dedicated to the transfer of fuels from a stationary pumping station to mobile vehicles or equipment. It includes above or under-ground fuel storage facilities. In addition to general service gas stations, fueling may also occur at 24-hour convenience stores, construction sites, warehouses, car washes, manufacturing establishments, port facilities, and businesses with fleet vehicles. Typically, stormwater contamination at fueling stations is caused by leaks/spills of fuels, lube oils, radiator coolants, and vehicle wash water.

Pollutant Control Approach: New or substantially remodeled* fueling stations must be constructed on an impervious concrete pad under a roof to keep out rainfall and stormwater run-on. A treatment BMP must be used for contaminated stormwater and wastewaters in the fueling containment area.

** Substantial remodeling includes replacing the canopy, or relocating or adding one or more fuel dispensers in such a way that the Portland cement concrete (or equivalent) paving in the fueling area is modified.*

For new or substantially remodeled fueling stations:

Applicable Operational BMPs:

- Prepare an emergency spill response and cleanup plan (per BMPs for Spills of Oil and Hazardous Substances) and have a designated trained person(s) available either on site or on call at all times to promptly and properly implement that plan and immediately cleanup all spills. Keep suitable cleanup materials, such as dry adsorbent materials, on site to allow prompt cleanup of a spill.

- Train employees on the proper use of fuel dispensers. Post signs in accordance with the Uniform Fire Code (UFC). Post "No Topping Off" signs (topping off gas tanks causes spillage and vents gas fumes to the air). Make sure that the automatic shutoff on the fuel nozzle is functioning properly.
- The person conducting the fuel transfer must be present at the fueling pump during fuel transfer, particularly at unattended or self-serve stations.
- Keep drained oil filters in a suitable container or drum.

Applicable Structural Source Control BMPs:

- Design the fueling island to control spills (dead-end sump or spill control separator in compliance with the UFC), and to treat collected stormwater and(or) wastewater to required levels. Slope the concrete containment pad around the fueling island toward drains; either trench drains, catch basins and(or) a dead-end sump. The slope of the drains shall not be less than 1 percent (Section 7901.8 of the UFC). Drains to treatment shall have a shutoff valve, which must be closed in the event of a spill. The spill control sump must be sized in compliance with Section 7901.8 of the UFC.
- Design the fueling island as a spill containment pad with a sill or berm raised to a minimum of four inches (Section 7901.8 of the UFC) to prevent the runoff of spilled liquids and to prevent run-on of stormwater from the surrounding area. Raised sills are not required at the open-grate trenches that connect to an approved drainage-control system.
- The fueling pad must be paved with Portland cement concrete, or equivalent. Asphalt is not considered an equivalent material.
- The fueling island must have a roof or canopy to prevent the direct entry of precipitation onto the spill containment pad (see Figure 8.3.1). The roof or canopy should, at a minimum, cover the spill containment pad (within the grade break or fuel dispensing area) and preferably extend several additional feet to reduce the introduction of windblown rain. Convey all roof drains to storm drains outside the fueling containment area.

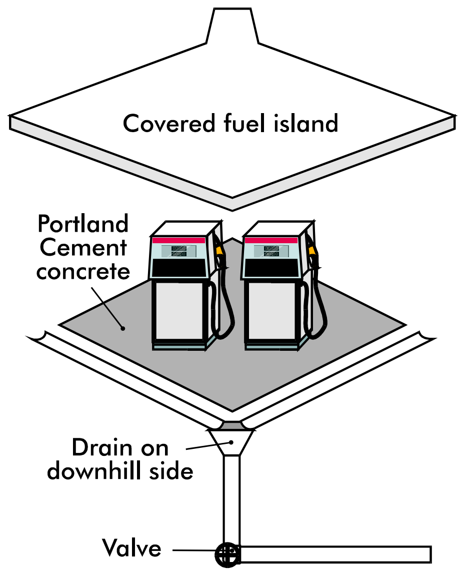

Figure 8.3.1 – Covered Fuel Island

- Stormwater collected on the fuel island containment pad must be conveyed to a sanitary sewer system, if approved by the sanitary authority; or to an approved treatment system such as an oil/water separator and a water quality treatment BMP. (Water quality treatment BMPs are listed in Chapter 5 and include media filters and biofilters.) Discharges from treatment systems to storm drains, to surface water, or to the ground must not display ongoing or recurring visible sheen and must not contain greater than a significant amount of oil and grease.
- Alternatively, stormwater collected on the fuel island containment pad may be collected and held for proper offsite disposal.
- Conveyance of any fuel-contaminated stormwater to a sanitary sewer must be approved by the local jurisdiction and must comply with pretreatment regulations (WAC 173-216-060). These regulations prohibit discharges that could “cause fire or explosion.” An explosive or flammable mixture is defined under state and federal pretreatment regulations based on a flash point determination of the mixture. If contaminated stormwater is determined not to be explosive, then it could be conveyed to a sanitary sewer system.
- Transfer the fuel from the delivery tank trucks to the fuel storage tank in impervious contained areas and ensure that appropriate overflow protection is used. Alternatively, cover nearby storm drains during the filling process and use drip pans under all hose connections.

Additional BMP for vehicles ten feet in height or greater:

A roof or canopy may not be practicable at fueling stations that regularly fuel vehicles ten feet in height or greater, particularly at industrial or WSDOT sites. At those types of fueling facilities, the following BMPs apply, as well as the applicable BMPs and fire prevention (UFC requirements) of this BMP for fueling stations:

- If a roof or canopy is impractical the concrete fueling pad must be equipped with emergency spill control that includes a shutoff valve for the drainage from the fueling area. The valve must be closed in the event of a spill. An electronically actuated valve is preferred to minimize the time lapse between spill and containment. Spills must be cleaned up and disposed off-site in accordance with BMPs for Spills of Oil and Hazardous Substances.
- The valve may be opened to convey contaminated stormwater to a sanitary sewer, if approved by the sewer authority, or to oil removal treatment such as an API or CP oil/water separator, catchbasin insert, or equivalent treatment, and then to a basic treatment BMP. Discharges from treatment systems to storm drains, or surface water or to the ground must not display ongoing or recurring visible sheen and must not contain greater than a significant amount of oil and grease.

An explosive or flammable mixture is defined under state and federal pretreatment regulations, based on a flash point determination of the mixture. If contaminated stormwater is determined not to be explosive or flammable, then it could be conveyed to a sanitary sewer system.

BMPs for Illicit Connections to Storm Drains

Description of Pollutant Sources: Illicit connections are unpermitted sanitary or process wastewater discharges to a storm drain or to surface water rather than to a sanitary sewer, industrial process wastewater or other appropriate treatment. They can also include swimming pool water, filter backwash, cleaning solutions/wash waters, cooling water, etc. Experience has shown that illicit connections are common, particularly in older buildings.

Pollutant Control Approach: Identify and eliminate unpermitted discharges or obtain an NPDES permit, where necessary, particularly at industrial and commercial facilities.

Applicable Operational BMPs:

- Eliminate unpermitted wastewater discharges to storm drains, groundwater, or surface water.
- Convey unpermitted discharges to a sanitary sewer if allowed by the local jurisdiction, or to other approved treatment.
- Obtain appropriate permits for these discharges.

Recommended Additional Operational BMPs: At commercial and industrial facilities conduct a survey of wastewater discharge connections to storm drains and to surface water as follows:

- Conduct a field survey of buildings, particularly older buildings, and other industrial areas to locate storm drains from buildings and paved surfaces. Note where these join the public storm drain(s).
- During non-stormwater conditions inspect each storm drain for non-stormwater discharges. Record the locations of all non-stormwater discharges. Include all permitted discharges.
- If useful, prepare a map of each area as it is to be surveyed. Show on the map the known location of storm drains, sanitary sewers, and permitted and unpermitted discharges. Aerial photos may be useful. Check records such as piping schematics to identify known side sewer connections and show these on the map. Consider using smoke, dye, or chemical analysis tests to detect connections between two conveyance systems (e.g., process water and stormwater). If desirable, conduct TV inspections of the storm drains and record the footage on videotape.
- Compare the observed locations of connections with the information on the map and revise the map accordingly. Note suspect connections inconsistent with the field survey.
- Identify all connections to storm drains or to surface water and take the actions specified above as applicable BMPs.

BMPs for Landscaping and Lawn/ Vegetation Management

Description of Pollutant Sources: Landscaping can include grading, soil transfer, vegetation removal, pesticide and fertilizer applications, and watering. Stormwater contaminants include toxic organic compounds, heavy metals, oils, total suspended solids, coliform bacteria, fertilizers, and pesticides.

Lawn and vegetation management can include control of objectionable weeds, insects, mold, bacteria and other pests with chemical pesticides and is conducted commercially at commercial, industrial, and residential sites. Examples include weed control on golf course lawns, access roads, utility corridors, and during landscaping; sap stain and insect control on lumber and logs; rooftop moss removal; killing nuisance rodents; fungicide application to patio decks, and residential lawn/plant care. Toxic pesticides such as pentachlorophenol, carbamates, and organometallics can be released to the environment by leaching and dripping from treated parts, container leaks, product misuse, and outside storage of pesticide contaminated materials and equipment. Poor management of the vegetation and poor application of pesticides or fertilizers can cause appreciable stormwater contamination.

Pollutant Control Approach: Control fertilizer and pesticide applications, soil erosion, and site debris to prevent contamination of stormwater. Develop and implement an Integrated Pest Management Plan (IPM) and use pesticides only as a last resort. If pesticides/herbicides are used they must be carefully applied in accordance with label instructions on U.S. Environmental Protection Agency (EPA) registered materials. Maintain appropriate vegetation, with proper fertilizer application where practicable, to control erosion and the discharge of stormwater pollutants. Where practicable grow plant species appropriate for the site, or adjust the soil properties of the subject site to grow desired plant species.

Applicable Operational BMPs for Landscaping:

- Install engineered soil/landscape systems to improve the infiltration and regulation of stormwater in landscaped areas.
- Do not dispose of collected vegetation into waterways or storm drainage systems.

Recommended Additional Operational BMPs for Landscaping:

- Conduct mulch-mowing whenever practicable
- Dispose of grass clippings, leaves, sticks, or other collected vegetation, by composting, if feasible.
- Use mulch or other erosion control measures when soils are exposed for more than one week.
- If oil or other chemicals are handled, store and maintain appropriate oil and chemical spill cleanup materials in readily accessible locations. Ensure that employees are familiar with proper spill cleanup procedures.
- Till fertilizers into the soil rather than dumping or broadcasting onto the surface. Determine the proper fertilizer application for the types of soil and vegetation encountered.
- Till a topsoil mix or composted organic material into the soil to create a well-mixed transition layer that encourages deeper root systems and drought-resistant plants.
- Use manual and(or) mechanical methods of vegetation removal rather than applying herbicides, where practical.

Applicable Operational BMPs for the Use of Pesticides:

- Develop and implement an IPM and use pesticides only as a last resort.
- Implement a pesticide-use plan and include at a minimum: a list of selected pesticides and their specific uses; brands, formulations, application methods and quantities to be used; equipment use and maintenance procedures; safety, storage, and disposal methods; and

monitoring, record keeping, and public notice procedures. All procedures shall conform to the requirements of Chapter 17.21 RCW and Chapter 16-228 WAC.

- Choose the least toxic pesticide available that is capable of reducing the infestation to acceptable levels. The pesticide should readily degrade in the environment and(or) have properties that strongly bind it to the soil. Any pest control used should be conducted at the life stage when the pest is most vulnerable. For example, if it is necessary to use a Bacillus thuringiens is application to control tent caterpillars, it must be applied before the caterpillars cocoon or it will be ineffective. Any method used should be site-specific and not used wholesale over a wide area.
- Apply the pesticide according to label directions. Under no conditions shall pesticides be applied in quantities that exceed manufacturer's instructions.
- Mix the pesticides and clean the application equipment in an area where accidental spills will not enter surface or ground waters, and will not contaminate the soil.
- Store pesticides in enclosed areas or in covered impervious containment. Ensure that pesticide contaminated stormwater or spills/leaks of pesticides are not discharged to storm drains. Do not hose down the paved areas to a storm drain or conveyance ditch. Store and maintain appropriate spill cleanup materials in a location known to all near the storage area.
- Clean up any spilled pesticides and ensure that the pesticide contaminated waste materials are kept in designated covered and contained areas.
- The pesticide application equipment must be capable of immediate shutoff in the event of an emergency.
- Do not spray non-permitted pesticides within 100 feet of open waters including wetlands, ponds, and streams, sloughs and any drainage ditch or channel that leads to open water except when approved by Ecology or the local jurisdiction. All sensitive areas including wells, creeks, and wetlands must be flagged prior to spraying.
- As required by the local government or by Ecology, complete public posting of the area to be sprayed prior to the application.
- Spray applications should only be conducted during weather conditions as specified in the label direction and applicable local and state regulations. Do not apply during rain or immediately before expected rain.

Recommended Additional Operational BMPs for the use of pesticides:

- Consider alternatives to the use of pesticides such as covering or harvesting weeds, substitute vegetative growth, and manual weed control/moss removal.
- Consider the use of soil amendments, such as compost, that are known to control some common diseases in plants, such as Pythium root rot, ashy stem blight, and parasitic nematodes. The following are three possible mechanisms for disease control by compost addition (USEPA Publication 530-F-9-044):

  1. Successful competition for nutrients by antibiotic production;
  2. Successful predation against pathogens by beneficial microorganism; and
  3. Activation of disease-resistant genes in plants by composts.

Installing an amended soil/landscape system can preserve both the plant system and the soil system more effectively. This type of approach provides a soil/landscape system with adequate depth, permeability, and organic matter to sustain itself and to continue working as an effective stormwater infiltration system and a sustainable nutrient cycle.

- Once a pesticide is applied, its effectiveness should be evaluated for possible improvement. Records should be kept showing the applicability and inapplicability of the pesticides considered.
- An annual evaluation procedure should be developed including a review of the effectiveness of pesticide applications, impact on buffers and sensitive areas (including potable wells), public concerns, and recent toxicological information on pesticides used/proposed for use. If individual or public potable wells are located in the proximity of commercial pesticide applications contact the regional Ecology hydrogeologist to determine if additional pesticide application control measures are necessary.
- Rinseate from equipment cleaning and(or) triple-rinsing of pesticide containers should be used as product or recycled into product.
- The application equipment used should be capable of immediate shutoff in the event of an emergency.

For more information, contact the WSU Extension Home-Assist Program, (253) 445-4556, or Bio-Integral Resource Center (BIRC), P.O. Box 7414, Berkeley, CA.94707, or the Washington Department of Ecology to obtain "Hazardous Waste Pesticides" (Publication #89-41); and(or) EPA to obtain a publication entitled "Suspended, Canceled and Restricted Pesticides" which lists all restricted pesticides and the specific uses *allowed. Valuable information from these sources may also be available on the internet.*

Applicable Operational BMPs for Vegetation Management:

- Use at least an eight-inch topsoil layer with at least eight percent organic matter to provide a sufficient vegetation-growing medium. Amending existing landscapes and turf systems by increasing the percent organic matter and depth of topsoil can substantially improve the permeability of the soil, the disease and drought resistance of the vegetation, and reduce fertilizer demand. This reduces the demand for fertilizers, herbicides, and pesticides. Organic matter is the least water-soluble form of nutrients that can be added to the soil. Composted organic matter generally releases only between two and ten percent of its total nitrogen each year, and this release corresponds closely to the plant growth cycle. If natural plant debris and mulch are returned to the soil, this system can continue recycling nutrients indefinitely.

- Select the appropriate turf grass mixture for your climate and soil type. Certain tall fescues and rye grasses resist insect attack, because the symbiotic endophytic fungi found naturally in their tissues repel or kill common leaf and stem-eating lawn insects. They do not, however, repel root-feeding lawn pests such as Crane Fly larvae, and are toxic to ruminants such as cattle and sheep. The fungus causes no known adverse effects to the host plant or to humans. Endophytic grasses are commercially available and can be used in areas such as parks or golf courses where grazing does not occur. The local Cooperative Extension office can offer advice on which types of grass are best suited to the area and soil type.

- Use the appropriate seeding and planting BMPs in Chapter 7, or equivalent BMPs, to obtain information on grass mixtures, temporary and permanent seeding procedures, maintenance of a recently planted area, and fertilizer application rates.

- Selection of desired plant species can be made by adjusting the soil properties of the subject site. For example, a constructed wetland can be designed to resist the invasion of reed canary grass by layering specific strata of organic matters (e.g., compost forest product residuals), and creating a mildly acidic pH and carbon-rich soil medium. Consult a soil restoration specialist for site-specific conditions.

- Aerate lawns regularly in areas of heavy use where the soil tends to become compacted. Aeration should be conducted while the grasses in the lawn are growing most vigorously. Remove layers of thatch greater than ¾-inch deep.

- Mowing is a stress-creating activity for turf grass. When grass is mowed too short its productivity is decreased and there is less growth of roots and rhizomes. The turf becomes less tolerant of environmental stresses, more disease prone, and more reliant on outside means, such as pesticides, fertilizers, and irrigation to remain healthy. Set the mowing height at the highest acceptable level and mow at times and intervals designed to minimize stress on the turf. Generally mowing only 1/3 of the grass blade height will prevent stressing the turf.

Irrigation:

- The depth from which a plant normally extracts water depends on the rooting depth of the plant. Appropriately irrigated lawn grasses normally root in the top six to twelve inches of soil; lawns irrigated on a daily basis often root only in the top one inch of soil. Improper irrigation can encourage pest problems, leach nutrients, and make a lawn completely dependent on artificial watering. The amount of water applied depends on the normal rooting depth of the turf grass species used, the available water holding capacity of the soil, and the efficiency of the irrigation system. Consult with the local water utility, Conservation District, or Cooperative Extension office to help determine optimum irrigation practices.

Fertilizer Management:

- Turf grass is most responsive to nitrogen fertilization, followed by potassium and phosphorus. Fertilization needs vary by site depending on plant, soil and climatic conditions. Evaluation of soil nutrient levels through regular testing ensures the best possible efficiency and economy of fertilization. For details on soils testing, contact the local Conservation District or Cooperative Extension Service.

- Fertilizers should be applied in amounts appropriate for the target vegetation and at the time of year that minimizes losses to surface and groundwaters. Do not fertilize during a drought or when the soil is dry. Alternatively, do not apply fertilizers within three days prior to predicted rainfall. The longer the period between fertilizer application and either rainfall or irrigation, the less fertilizer runoff occurs.

- Use slow release fertilizers such as methylene urea, IDBU, or resin coated fertilizers, when appropriate, generally in the spring. Use of slow release fertilizers is especially important in areas with sandy or gravelly soils.

- Time the fertilizer application to periods of maximum plant uptake. Generally fall and spring applications are recommended, although WSU turf specialists recommend four fertilizer applications per year.

- Properly trained persons should apply all fertilizers. At commercial and industrial facilities fertilizers should not be applied to grass swales, filter strips, or buffer areas that drain to sensitive water bodies unless approved by the local jurisdiction.

Integrated Pest Management:

An IPM program might consist of the following steps:

Step 1: Correctly identify problem pests and understand their life cycle.
Step 2: Establish tolerance thresholds for pests.
Step 3: Monitor to detect and prevent pest problems.
Step 4: Modify the maintenance program to promote healthy plants and discourage pests.
Step 5: Use cultural, physical, mechanical, or biological controls first when pests exceed the tolerance thresholds.
Step 6: Evaluate and record the effectiveness of the control, and modify maintenance practices to support lawn or landscape recovery and prevent recurrence.

For an elaboration of these steps refer to Appendix IV-F in the Stormwater Management Manual for Western Washington*, Ecology Publication #99-15, August 2001.*

BMPs for Loading and Unloading Areas for Liquid or Solid Material

Description of Pollutant Sources: Loading/unloading of liquid and solid materials at industrial and commercial facilities are typically conducted at shipping and receiving, outside storage, fueling areas, etc. Materials transferred can include products, raw materials, intermediate products, waste materials, fuels, scrap metals, etc. Leaks and spills of fuels, oils, powders, organics, heavy metals, salts, acids, alkalis, etc. during transfer are potential causes of stormwater contamination. Spills from hydraulic line breaks are a common problem at loading docks.

Pollutant Control Approach: Cover and contain the loading/unloading area, where necessary, to prevent run-on of stormwater and runoff of contaminated stormwater.

Applicable Operational BMPs:

At All Loading/Unloading Areas:

- A significant amount of debris can accumulate at outside, uncovered loading/unloading areas. Sweep these surfaces frequently to remove material that could otherwise be washed off by stormwater. Sweep outside areas that are covered, for a period of time, by containers, logs, or other material after the areas are cleared.
- Place drip pans, or other appropriate temporary containment device, at locations where leaks or spills may occur, such as hose connections, hose reels, and filler nozzles. Drip pans shall always be used when making and breaking connections (see Figure 8.3.2). Check loading/unloading equipment, such as valves, pumps, flanges, and connections regularly for leaks and repair, as needed.

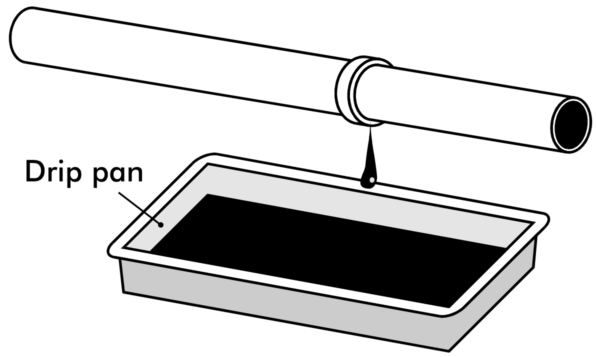

Figure 8.3.2 – Drip pan

At Tanker Truck and Rail Transfer Areas to Above/Below-Ground Storage Tanks:

- To minimize the risk of accidental spillage, prepare an "Operations Plan" that describes procedures for loading/unloading. Train the employees, especially fork lift operators, in its execution and post it, or otherwise have it readily available to employees.
- Report spills of reportable quantities to Ecology (refer to Section 8.3.1.5 for telephone numbers of Ecology Regional Offices).
- Prepare and implement an Emergency Spill Cleanup Plan for the facility (BMP Spills of Oil and Hazardous Substances) which includes the following BMPs:
  - Ensure the clean up of liquid/solid spills in the loading/unloading area immediately, if a significant spill occurs, and upon completion of the loading/unloading activity, or at the end of the working day.
  - Retain and maintain an appropriate oil spill cleanup kit on-site for rapid cleanup of material spills. (See BMP "Spills of Oil and Hazardous Substances.")
  - Ensure that an employee trained in spill containment and cleanup is present during loading/unloading.

At Rail Transfer Areas to Above/Below-Ground Storage Tanks: Install a drip pan system as illustrated (see Figure 8.3.3) within the rails to collect spills/leaks from tank cars and hose connections, hose reels, and filler nozzles.

Loading/Unloading from/to Marine Vessels: Facilities and procedures for the loading or unloading of petroleum products must comply with Coast Guard requirements.

Transfer of Small Quantities from Tanks and Containers: Refer to BMPs Storage of Liquids in Permanent Above-Ground Tanks, and Storage of Liquid, Food Waste, or Dangerous Waste Containers, for

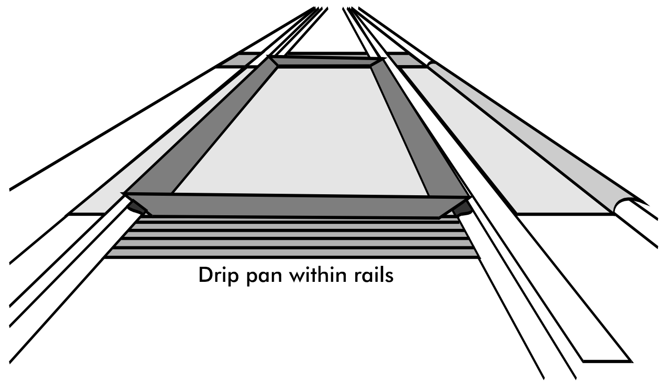

Figure 8.3.3 – Drip pan within rails

requirements on the transfer of small quantities from tanks and containers, respectively.

Applicable Structural Source Control BMPs:

At All Loading/ Unloading Areas:

- Consistent with Uniform Fire Code requirements and to the extent practicable, conduct unloading or loading of solids and liquids in a manufacturing building, under a roof, or lean-to, or other appropriate cover.
- Berm, dike, and(or) slope the loading/unloading area to prevent run-on of stormwater and to prevent the runoff or loss of any spilled material from the area.
- Pave and slope loading/unloading areas to prevent the pooling of water. The use of catch basins and drain lines within the interior of the paved area must be minimized as they will frequently be covered by material, or they should be placed in designated “alleyways” that are not covered by material, containers or equipment.

Recommended Structural Source Control BMP: For the transfer of pollutant liquids in areas that cannot contain a catastrophic spill, install an automatic shutoff system in case of unanticipated off-loading interruption (e.g., coupling break, hose rupture, overfill, etc.).

At Loading and Unloading Docks:

- Install/maintain overhangs, or door skirts that enclose the trailer end (see Figures 8.3.4 and 8.3.5) to prevent contact with rain water.
- Design the loading/unloading area with berms, sloping, etc. to prevent the run-on of stormwater.
- Retain on-site the necessary materials for rapid cleanup of spills.

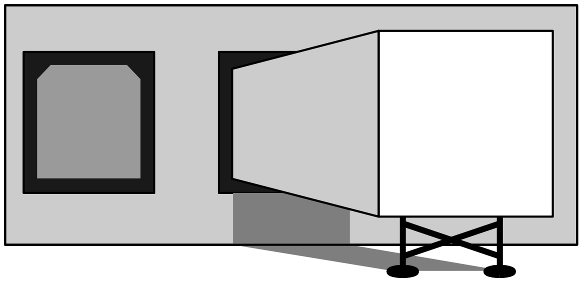

Figure 8.3.4 – Loading dock with door skirt

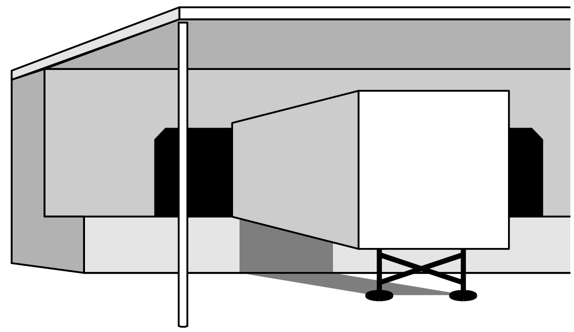

Figure 8.3.5 – Loading dock with overhang

At Tanker Truck Transfer Areas to Above/Below-Ground Storage Tanks:

- Pave the area on which the transfer takes place. If any transferred liquid, such as gasoline, is reactive with asphalt, pave the area with Portland cement concrete.
- Slope, berm, or dike the transfer area to a dead-end sump, spill containment sump, a spill control (SC) oil/water separator, or other spill control device. The minimum spill retention time should be 15 minutes at the greater flow rate of the highest fuel dispenser nozzle through-put rate, or the peak flow rate of the 6-month, 24-hour storm event over the surface of the containment pad, whichever is greater. The volume of the spill containment sump should be a minimum of 50 gallons with an adequate grit sedimentation volume.

BMPs for Log Sorting and Handling

Description of Pollutant Sources: Log yards are paved or unpaved areas where logs are transferred, sorted, debarked, cut, and stored to prepare them for shipment or for the production of dimensional lumber, plywood, chips, poles, or other products. Log yards are generally maintained at sawmills, shipping ports, and pulp mills. Typical pollutants include oil and grease, BOD, settleable solids, total suspended solids (including soil), high and low pH, heavy metals, pesticides, wood-based debris, and leachate.

The following are pollutant sources:

- Log storage, rollout, sorting, scaling, and cutting areas
- Log and liquid loading areas
- Log sprinkling
- Debarking, bark bin, and conveyor areas
- Bark, ash, sawdust and wood debris piles, and other solid wastes
- Metal salvage areas
- Truck, rail, ship, stacker, and loader access areas
- Log trucks, stackers, loaders, forklifts, and other heavy equipment
- Maintenance shops and parking areas
- Cleaning areas for vehicles, parts, and equipment
- Storage and handling areas for hydraulic oils, lubricants, fuels, paints, liquid wastes, and other liquid materials
- Pesticide usage for log preservation and surface protection
- Application of herbicides for weed control
- Contaminated soil resulting from leaks or spills of fluids

Ecology's Current Industrial Stormwater General Permit Requirements: Industries with log yards are required to obtain coverage under the current industrial stormwater general permit for discharges of stormwater associated with industrial activities to surface water. The permit requires preparation and on-site retention of Stormwater Pollution Prevention Plans (SWPPP). The SWPPP must identify operational, source control, erosion and sediment control and, if necessary, treatment BMPs. Required and recommended operational, source control, and treatment BMPs are presented in detail in Ecology's Guidance Document: "Best Management Practices to Prevent Stormwater Pollution at Log Yards," Publication # 95-053, May 1995. It is recommended that all log yard facilities obtain a copy of this document.

BMPs for Maintenance and Repair of Vehicles and Equipment

Description of Pollutant Sources: Pollutant sources include parts/vehicle cleaning, spills/leaks of fuel and other liquids, replacement of liquids, outdoor storage of batteries/liquids/parts, and vehicle parking.

Pollutant Control Approach: Control of leaks and spills of fluids using good housekeeping, and cover and containment BMPs.

Applicable Operational BMPs:

- Inspect for leaks all incoming vehicles, parts, and equipment stored temporarily outside.

- Use drip pans or containers under parts or vehicles that drip or are likely to drip liquids, such as during dismantling of liquid containing parts, or removal or transfer of liquids.

- Remove batteries and liquids from vehicles and equipment in designated areas designed to prevent stormwater contamination. Store cracked batteries in a covered non-leaking secondary containment system.

- Empty oil and fuel filters before disposal. Provide for proper disposal of waste oil and fuel.
- Do not pour/convey wash water, liquid waste, or other pollutant into storm drains or to surface water. Check with the local jurisdiction for approval to convey to a sanitary sewer.
- Do not connect maintenance and repair shop floor drains to storm drains or to surface water. To allow for snowmelt during the winter a drainage trench with a sump for particulate collection can be installed and used only for draining the snowmelt and not for discharging any vehicular or shop pollutants.

Applicable Structural Source Control BMPs:

- Conduct all maintenance and repair of vehicles and equipment in a building, or other covered impervious containment area sloped to prevent run-on of uncontaminated stormwater and runoff of contaminated stormwater.
- The maintenance of refrigeration engines in refrigerated trailers may be conducted in the parking area with due caution to avoid the release of engine or refrigeration fluids to storm drains or surface water.
- Park large mobile equipment, such as log stackers, in a designated contained area.

For additional applicable BMPs refer to the following BMPs: Fueling at Dedicated Stations; Washing and Steam Cleaning Vehicle/Equipment/ Building Structures; Loading and Unloading Areas for Liquid or Solid Material; Storage of Liquids in Permanent Above-Ground Tanks; Storage of Liquid, Food Waste, or Dangerous Waste Containers; Storage or Transfer (Outside) of Solid Raw Materials, By-Products, or Finished Products; Spills of Oil and Hazardous Substances; Illicit Connections to Storm Drains; and other BMPs provided in this chapter.

Applicable Treatment BMPs: Contaminated stormwater runoff from vehicle staging and maintenance areas must be conveyed to a sanitary sewer, if allowed by the local jurisdiction, or to an API or CP oil and water separator followed by a water quality treatment BMP (see Chapter 5), applicable filter, or other equivalent oil treatment system.

***Note**: A treatment BMP is applicable for contaminated stormwater.*

Recommended Additional Operational BMPs:

- Consider storing damaged vehicles inside a building or other covered containment, until all liquids are removed. Remove liquids from vehicles retired for scrap.
- Clean parts with aqueous detergent based solutions or non-chlorinated solvents, such as kerosene or high flash mineral spirits, and(or) use wire brushing or sand blasting whenever practicable. Avoid using

toxic liquid cleaners, such as methylene chloride, 1,1,1-trichloroethane, trichloroethylene or similar chlorinated solvents. Choose cleaning agents that can be recycled.

- Inspect all BMPs regularly, particularly after a significant storm. Identify and correct deficiencies to ensure that the BMPs are functioning as intended.
- Avoid hosing down work areas. Use dry methods for cleaning leaked fluids.
- Recycle greases, used oil, oil filters, antifreeze, cleaning solutions, automotive batteries, hydraulic fluids, transmission fluids, and engine oils (see Appendix IV-C of the SWMMWW).
- Do not mix dissimilar or incompatible waste liquids stored for recycling.

BMPs for Maintenance of Public and Private Utility Corridors and Facilities

Description of Pollutant Sources: Passageways and equipment at petroleum product, natural gas lines, water pipelines, and electrical power transmission corridors and rights-of-way can be sources of pollutants, such as herbicides used for vegetation management, and eroded soil particles from unpaved access roads. At pump stations waste materials generated during maintenance activities may be temporarily stored outside. Additional potential pollutant sources include: the leaching of preservatives from wood utility poles, PCBs in older transformers, water removed from underground transformer vaults, and leaks/spills from petroleum pipelines. The following are potential pollutants: oil and grease, TSS, BOD, organics, PCB, pesticides, and heavy metals.

Pollutant Control Approach: Control of fertilizer and pesticide applications, soil erosion, and site debris that can contaminate stormwater.

Applicable Operational BMPs:

- Implement BMPs for landscaping and lawn/vegetation management.
- When water or sediments are removed from electric transformer vaults, determine whether contaminants might be present before disposing of the water and sediments. This includes inspecting for the presence of oil or sheen, and determining from records or testing if the transformers contain PCBs. If records or tests indicate that the sediment or water are contaminated above applicable levels, manage these media in accordance with applicable federal and state regulations, including the federal PCB rules (40 CFR 761) and the state MTCA cleanup regulations (Chapter 173-340 WAC). Water removed from the vaults can be discharged in accordance with the federal 40 CFR 761.79, and state regulations (Chapter 173-201A WAC and Chapter 173-200 WAC), or via the sanitary sewer if the requirements, including applicable permits, for such a discharge are met.

- Within utility corridors, consider preparing maintenance procedures and an implementation schedule that provides for a vegetative, gravel, or equivalent cover that minimizes bare or thinly vegetated ground surfaces within the corridor, to prevent the erosion of soil.
- Provide maintenance practices to prevent stormwater from accumulating and draining across and(or) onto roadways. Stormwater should be conveyed through roadside ditches and culverts. The road should be crowned, outsloped, water barred or otherwise left in a condition not conducive to erosion. Appropriately maintaining grassy roadside ditches discharging to surface waters is an effective way of removing some pollutants associated with sediments carried by stormwater.
- Maintain ditches and culverts at an appropriate frequency to ensure that plugging and flooding across the roadbed, with resulting overflow erosion, does not occur.
- Apply the appropriate BMPs in this chapter for the storage of waste materials that can contaminate stormwater.

Recommended Operational BMPs:

- When selecting utility poles for a specific location, consideration should be given to the potential environmental effects of the pole or poles during storage, handling, and end-use, as well as its cost, safety, efficacy, and expected life. If a wood product treated with chemical preservatives is used, it should be made in accordance with generally accepted industry standards such as the American Wood Preservers Association Standards. If the pole or poles will be placed in or near an environmentally sensitive area, such as a wetland or a drinking water well, alternative materials or technologies should be considered. These include poles constructed with material(s) other than wood, such as fiberglass composites, metal, or concrete. Other technologies and materials, such as sleeves or caissons for wood poles, may also be considered when they are determined to be practicable and available.
- As soon as practicable remove all litter from wire cutting/replacing operations, etc.
- Implement temporary erosion and sediment control in areas where clear-cuts are conducted and new roads are constructed.

BMPs for Maintenance of Roadside Ditches

Description of Pollutant Sources: Common road debris, including eroded soil, oils, vegetative particles, and heavy metals, can be a source of stormwater pollutants.

Pollutant Control Approach: Roadside ditches should be maintained to preserve the condition and capacity for which they were originally constructed, and to minimize bare or thinly vegetated ground surfaces. Maintenance practices should provide for erosion and sediment control.

(Refer to BMP Landscaping and Lawn/Vegetation Management.)

Applicable Operational BMPs:

- Inspect roadside ditches regularly, as needed, to identify sediment accumulations and localized erosion.
- Clean ditches on a regular basis, as needed. Ditches should be kept free of rubbish and debris.
- In situations where appropriate, vegetation in ditches often prevents erosion and cleanses runoff waters. Remove vegetation only when flow is blocked or excess sediments have accumulated. Conduct ditch maintenance (seeding, fertilizer application, harvesting) in late spring and(or) early fall, where possible. This allows vegetative cover to be re-established by the next wet season, thereby minimizing erosion of the ditch as well as making the ditch effective as a biofilter.
- In the area between the edge of the pavement and the bottom of the ditch, commonly known as the “bare earth zone,” use grass vegetation, wherever possible. Vegetation should be established from the edge of the pavement, if possible, or at least from the top of the slope of the ditch.
- Diversion ditches on top of cut slopes that are constructed to prevent slope erosion by intercepting surface drainage must be maintained to retain their diversion shape and capability.
- Ditch cleanings are not to be left on the roadway surfaces. Sweep dirt and debris remaining on the pavement at the completion of ditch cleaning operations.
- Roadside ditch cleanings, not contaminated by spills or other releases and not associated with a stormwater treatment system, such as a bioswale, may be screened to remove litter and separated into soil and vegetative matter (leaves, grass, needles, branches, etc.). The soil fraction may be handled as ‘clean soils’ and the vegetative matter can be composted or disposed of in a municipal waste landfill.
- Roadside ditch cleanings contaminated by spills or other releases known, or suspected, to contain dangerous waste must be handled following the Dangerous Waste Regulations (Chapter 173-303 WAC), unless testing determines it is not dangerous waste.
- Examine culverts on a regular basis for scour or sedimentation at the inlet and outlet and repair, as necessary. Give priority to those culverts conveying perennial and(or) salmon-bearing streams and culverts near streams in areas of high sediment load, such as those near subdivisions during construction.

Recommended Treatment BMPs:

- Install biofiltration swales and filter strips (see Chapter 5) to treat roadside runoff, wherever practicable, and use engineered topsoils, wherever necessary, to maintain adequate vegetation (CH2M Hill, 2000). These systems can improve infiltration and stormwater pollutant control upstream of roadside ditches.

BMPs for Maintenance of Stormwater Drainage and Treatment Systems

Description of Pollutant Sources: Facilities include roadside catch basins on arterials and within residential areas, conveyance systems, detention facilities, such as ponds and vaults, oil and water separators, biofilters, settling basins, infiltration systems, and all other types of stormwater treatment systems presented in Chapter 5. Roadside catch basins can remove from 5 to 15 percent of the pollutants present in stormwater. When catch basins are about 60 percent full of sediment, they cease removing sediments. Oil and grease, hydrocarbons, debris, heavy metals, sediments, and contaminated water are found in catch basins, oil and water separators, settling basins, etc.

Pollutant Control Approach: Provide maintenance and cleaning of debris, sediments, and oil from stormwater collection, conveyance, and treatment systems to obtain proper operation.

Applicable Operational BMPs: Maintain stormwater treatment facilities according to the operation and maintenance (O&M) procedures presented in this manual in addition to the following BMPs:

- Inspect and clean treatment BMPs, conveyance systems, and catch basins, as needed, and determine whether improvements in O&M are needed.
- Promptly repair any deterioration threatening the structural integrity of the facilities. These include: replacement of clean-out gates, catch basin lids, and rock in emergency spillways.
- Ensure that storm sewer capacities are not exceeded and that heavy sediment discharges to the sewer system are prevented.
- Regularly remove debris and sludge from BMPs used for peak-rate control, treatment, etc., and discharge to a sanitary sewer, if approved by the local jurisdiction, or truck to a local or state government approved disposal site.
- Clean catch basins when the depth of deposits reaches 60 percent of the sump depth, as measured from the bottom of basin to the invert of the lowest pipe into or out of the basin. However, in no case should there be less than six inches clearance from the debris surface to the invert of the lowest pipe. Some catch basins (for example, WSDOT Type 1L basins) may have as little as 12 inches sediment storage below the invert. These catch basins will need more frequent inspection and cleaning to prevent scouring. Where these catch basins are part of a stormwater collection and treatment system, the system owner/operator may choose to concentrate maintenance efforts on

downstream control devices as part of a systems approach.

- Clean woody debris in a catch basin as frequently as needed to ensure proper operation of the catchbasin.
- Post warning signs; "Dump No Waste - Drains to Groundwater," "Streams," "Lakes," or emboss on or adjacent to all storm drain inlets where practical.
- Disposal of sediments and liquids from the catch basins must comply with "Recommendations for Management of Street Wastes" described in Appendix 8B.

Additional Applicable BMPs: Select additional applicable BMPs from this chapter depending on the pollutant sources and activities conducted at the facility. Those BMPs include:

- BMPs for Soil Erosion and Sediment Control at Industrial Sites
- BMPs for Storage of Liquid, Food Waste, or Dangerous Waste Containers
- BMPs for Spills of Oil and Hazardous Substances
- BMPs for Illicit Connections to Storm Drains
- BMPs for Urban Streets

BMPs for Manufacturing Activities - Outside

Description of Pollutant Sources: Manufacturing pollutant sources include outside process areas, stack emissions, and areas where manufacturing activity has taken place in the past, and significant pollutant materials remain and are exposed to stormwater.

Pollution Control Approach: Cover and contain outside manufacturing and prevent stormwater run-on and contamination, where feasible.

Applicable Operational BMP: Sweep paved areas regularly, as needed, to prevent contamination of stormwater.

Applicable Structural Source Control BMPs:

- Alter the activity by eliminating or minimizing the contamination of stormwater.
- Enclose the activity (see Figure 8.3.6). If possible, enclose the manufacturing activity in a building.
- Cover the activity and connect floor drains to a sanitary sewer, if approved by the local jurisdiction. Berm or slope the floor, as needed, to prevent drainage of pollutants to outside areas (see Figure 8.3.7).
- Isolate and segregate pollutants, as feasible. Convey the segregated pollutants to a sanitary sewer, process treatment or a dead-end sump, depending on available methods and applicable permit requirements.

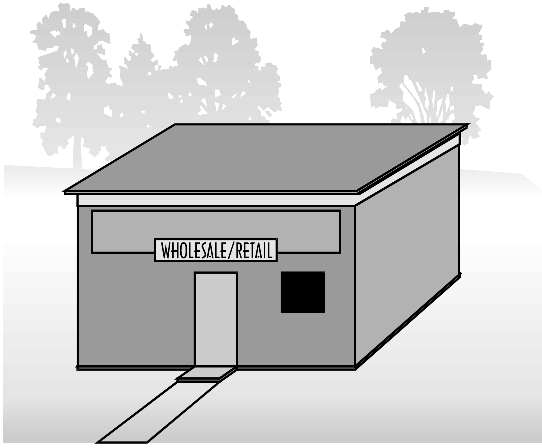

Figure 8.3.6 – Enclose the Activity

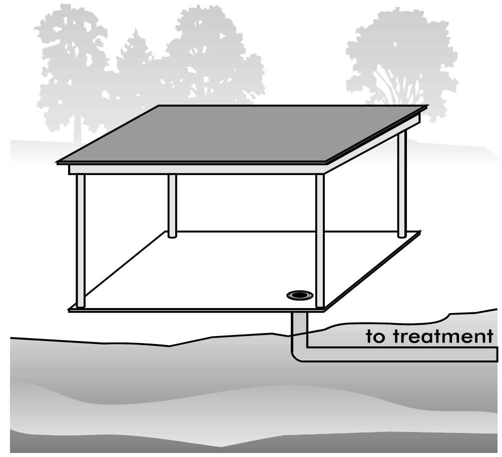

Figure 8.3.7 – Cover the Activity

BMPs for Mobile Fueling of Vehicles and Heavy Equipment

Description of Pollutant Sources: Mobile fueling, also known as fleet fueling, wet fueling, or wet hosing, is the practice of filling fuel tanks of vehicles by tank trucks driven to the yards or sites where the vehicles to be fueled are located. Mobile fueling is only conducted using diesel fuel, as mobile fueling of gasoline is prohibited. Diesel fuel is considered as a Class II Combustible Liquid, whereas gasoline is considered as a Flammable Liquid.

Historically mobile fueling has been conducted for off-road vehicles operated for extended periods of time in remote areas. This includes construction sites, logging operations, and farms. Mobile fueling of on-road vehicles is also conducted commercially in the state of Washington.

Note: *some local fire departments may have restrictions on mobile fueling practices.*

Pollutant Control Approach: Proper training of the fueling operator, and the use of spill/drip control and reliable fuel transfer equipment with backup shutoff valving are typically needed.

Applicable Operational BMPs: Organizations and individuals conducting mobile fueling operations must implement the following BMPs. The operating procedures for the driver/operator should be simple, clear, effective, and their implementation verified by the organization that will potentially be liable for environmental and third party damage.

- Ensure that all mobile fueling operations are approved by the local fire department and comply with local and state fire codes.
- In fueling locations that are in close proximity to sensitive aquifers, designated wetlands, wetland buffers, or other waters of the state, approval by local jurisdictions is necessary to ensure compliance with additional local requirements.

- Ensure the compliance with all 49 CFR 178 requirements for DOT 406 cargo tanker. Documentation from a Department of Transportation (DOT) registered inspector shall be proof of compliance.
- Ensure the presence and the constant observation and monitoring of the driver/operator at the fuel transfer location at all times during fuel transfer, and ensure that the following procedures are implemented at the fuel transfer locations:
  - Locating the point of fueling at least 25 feet from the nearest storm drain or inside an impervious containment with a volumetric holding capacity, equal to or greater than 110 percent of the fueling tank volume, or covering the storm drain to ensure no inflow of spilled or leaked fuel. Storm drains that convey the inflow to a spill control separator, approved by the local jurisdiction and the fire department, need not be covered. Potential spill/leak conveyance surfaces must be impervious and in good repair.
  - Placement of a drip pan, or an absorbent pad under each fueling location prior to and during all dispensing operations. The pan (must be liquid tight) and the absorbent pad must have a capacity of 5 gallons. Spills retained in the drip pan or the pad need not be reported.
  - The handling and operation of fuel transfer hoses and nozzle, drip pan(s), and absorbent pads, as needed, to prevent spills/leaks of fuel from reaching the ground, storm drains, and receiving waters.
  - Not extending the fueling hoses across a traffic lane without fluorescent traffic cones, or equivalent devices, conspicuously placed, so that all traffic is blocked from crossing the fuel hose.
  - Removing the fill nozzle and cessation of filling when the automatic shut-off valve engages. Do not allow automatic shutoff fueling nozzles to be locked in the open position.
  - Not “topping off” the fuel receiving equipment.
- Provide the driver/operator of the fueling vehicle with:
  - Adequate flashlights or other mobile lighting to view fill openings with poor accessibility. Consult with local fire department for additional lighting requirements.
  - Two-way communication with the home base.
- Train the driver/operator annually in spill prevention and cleanup measures and emergency procedures. Make all employees aware of the significant liability associated with fuel spills.
- The fueling operating procedures should be properly signed and dated

by the responsible manager, distributed to the operators, retained in the organization files, and made available in the event an authorized government agency requests a review.

- Ensure that the local fire department (911) and the appropriate regional office of the Department of Ecology are immediately notified in the event of any spill entering the surface or ground waters. Establish a "call down list" to ensure the rapid and proper notification of management and government officials should any significant amount of product be lost off-site. Keep the list in a protected, but readily accessible, location in the mobile fueling truck. The "call down list" should also pre-identify spill response contractors available in the area to ensure the rapid removal of significant product spillage into the environment.
- Maintain a minimum of the following spill clean-up materials in all fueling vehicles that are readily available for use:
  - Non-water absorbents capable of absorbing 15 gallons of diesel fuel;
  - A storm drain plug or cover kit;
  - A non-water absorbent containment boom of a minimum 10 feet in length with a 12-gallon absorbent capacity;
  - A non-metallic shovel; and
  - Two, five-gallon buckets with lids.
- Use automatic shutoff nozzles for dispensing the fuel. Replace automatic shut-off nozzles as recommended by the manufacturer.
- Maintain and replace equipment on fueling vehicles, particularly hoses and nozzles, at established intervals to prevent failures.

Applicable Structural Source Control BMPs: Include the following fuel transfer site components:

- Automatic fuel transfer shut-off nozzles; and
- An adequate lighting system at the filling point.

BMPs for Painting/ Finishing Coating of Vehicles/Boats/ Buildings/ Equipment

Description of Pollutant Sources: Surface preparation and the application of paints, finishes and(or) coatings to vehicles, boats, buildings, and(or) equipment outdoors can be sources of pollutants. Potential pollutants include organic compounds, oils and greases, heavy metals, and suspended solids.

Pollutant Control Approach: Cover and contain painting and sanding operations and apply good housekeeping and preventive maintenance practices to prevent the contamination of stormwater with painting oversprays and grit from sanding.

Applicable Operational BMPs:

- Train employees in the careful application of paints, finishes, and coatings to reduce misuse and over spray. Use ground or drop cloths underneath outdoor painting, scraping, sandblasting work, and properly clean and temporarily store collected debris daily.
- Do not conduct spraying, blasting, or sanding activities over open water, or where wind may blow paint into water.
- Wipe up spills with rags and other absorbent materials immediately. Do not hose down the area to a storm drain, receiving water, or conveyance ditch to receiving water.
- On dock areas sweep rather than hose down debris. Collect any hose water generated and convey to appropriate treatment and disposal.
- Use a storm drain cover, filter fabric, or similarly effective runoff control device if dust, grit, wash water, or other pollutants may escape the work area and enter a catch basin. The containment device(s) must be in place at the beginning of the workday. Collect contaminated runoff and solids, and properly dispose of such wastes before removing the containment device(s) at the end of the workday.
- Use a ground cloth, pail, drum, drip pan, tarpaulin, or other protective device for activities such as paint mixing and tool cleaning outside or where spills can contaminate stormwater. Properly dispose of all wastes and prevent all uncontrolled releases to the air, ground, or water.
- Clean brushes and tools covered with non-water-based paints, finishes, or other materials in a manner that allows collection of used solvents (e.g., paint thinner, turpentine, xylol, etc.) for recycling or proper disposal.
- Store toxic materials under cover (tarp, etc.) during precipitation events and when not in use to prevent contact with stormwater.

Applicable Structural Source Control BMPs: Enclose and(or) contain all work while using a spray gun or conducting sand blasting and in compliance with applicable air pollution control, OSHA, and WISHA requirements. Do not conduct outside spraying, grit blasting, or sanding activities during windy conditions which render containment ineffective.

Recommended Additional Operational BMPs:

- Clean paintbrushes and tools covered with water-based paints in sinks connected to sanitary sewers or in portable containers that can be dumped into a sanitary sewer drain.
- Recycle paint, paint thinner, solvents, pressure wash water, and any other recyclable materials.

- Use efficient spray equipment, such as electrostatic, air-atomized, high volume/low pressure, or gravity feed spray equipment.
- Purchase recycled paints, paint thinner, solvents, and other products, if feasible.

BMPs for Parking and Storage of Vehicles and Equipment

Description of Pollutant Sources: Public and commercial parking lots, such as retail store, fleet vehicle (including rent-a-car lots and car dealerships), equipment sale and rental parking lots, and parking lot driveways can be sources of toxic hydrocarbons and other organic compounds, oils and greases, metals, and suspended solids caused by the parked vehicles.

Pollutant Control Approach: If the parking lot is a high-use site, as defined below, provide appropriate oil removal equipment for the contaminated stormwater runoff.

Applicable Operational BMPs:

- If washing of a parking lot is conducted, discharge the wash water to a sanitary sewer, if allowed by the local jurisdiction or other approved wastewater treatment system, or collect it for off-site disposal.
- Do not hose down the area to a storm drain or to a receiving water. Sweep parking lots, storage areas, and driveways regularly to collect dirt, waste, and debris.

Applicable Treatment BMPs: An oil removal system such as an API or CP oil and water separator, catch basin filter, or equivalent BMP, approved by the local jurisdiction, is applicable for parking lots meeting the threshold vehicle traffic intensity level of a high-use site. See applicable BMP requirements in Chapters 5 and 6.

Vehicle High-Use Sites

Establishments subject to a vehicle high-use intensity have been determined to be significant sources of oil contamination of stormwater. Examples of potential high use areas include: customer parking lots at fast food stores, grocery stores, taverns, restaurants, large shopping malls, discount warehouse stores, quick-lube shops, and banks. If the PGIS for a high-use site exceeds 5,000 square feet, oil control BMP from the “Oil Control Menu” is necessary. A high-use site at a commercial or industrial establishment has one of the following characteristics (Gaus/King County, 1994):

- Is subject to an expected average daily vehicle traffic (ADT) count equal to or greater than 100 vehicles per 1,000 square feet of gross building area; or
- Is subject to storage of a fleet of 25 or more diesel vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.).

BMPs for Railroad Yards

Description of Pollutant Sources: Pollutant sources can include: drips/leaks of vehicle fluids onto the railroad bed, human waste disposal, litter, locomotive/railcar/equipment cleaning areas, fueling areas, outside material storage areas, the erosion and loss of soil particles from the railroad bed, maintenance and repair activities at railroad terminals, switching and maintenance yards, and herbicides used for vegetation management. Waste materials can include: waste oil, solvents, degreasers, antifreeze solutions, radiator flush, acids, brake fluids, soiled rags, oil filters, sulfuric acid and battery sludges, and machine chips with residual machining oil and toxic fluids/solids lost during transit. Potential pollutants include oil and grease, TSS, BOD, organics, pesticides, and metals.

Pollutant Control Approach: Apply good housekeeping and preventive maintenance practices to control leaks and spills of liquids in railroad yard areas.

Applicable Operational and Structural Source Control BMPs:

- Implement the applicable BMPs in this chapter depending on the pollutant generating activities/sources at a railroad yard facility.
- Do not allow discharge to outside areas from toilets while a train is in transit. Pump-out facilities should be used to service these units. Use drip pans at hose/pipe connections during liquid transfer and other leak-prone areas.
- During maintenance do not discard debris or waste liquids along the tracks or in railroad yards.

Applicable Treatment BMPs: In areas subjected to leaks/spills of oils or other chemicals convey the contaminated stormwater to appropriate treatment, such as a sanitary sewer, if approved by the appropriate local jurisdiction, or to a CP or API oil/water separator for floating oils or other treatment as approved by the local jurisdiction.

BMPs for Recyclers and Scrap Yards

Description of Pollutant Sources: Includes businesses that reclaim various materials for resale or for scrap, such as vehicles and vehicle/equipment parts, construction materials, metals, beverage containers, and papers.

Potential sources of pollutants include: paper, plastic, metal scrap debris, engines, transmissions, radiators, batteries, and other materials that contain fluids or are contaminated with fluids. Other pollutant sources include: leachate from metal components, contaminated soil, and the erosion of soil. Activities, generally in uncovered areas, that can generate pollutants include: transfer, dismantling, and crushing of vehicles and scrap metal; transfer and removal of fluids; maintenance and cleaning of vehicles, parts, and equipment; and storage of fluids, parts for resale, solid wastes, scrap parts; and storage of materials, equipment, and vehicles that contain fluids.

Potential pollutants typically found at vehicle recycle and scrap yards include oil and grease, ethylene and propylene glycol, total suspended solids, BOD, heavy metals, and acidic pH.

Applicable BMPs: For facilities subject to Ecology's Industrial Stormwater General Permit refer to Ecology the BMP Guidance Document "Best Management Practices to Prevent Stormwater Pollution at Vehicle Recycler Facilities," Publication #94-146, September 1994, for selection of BMPs. The BMPs in that guidance document can also be applied to scrap material recycling facilities depending on the pollutant sources existing at those facilities and to non-permitted facilities.

BMPs for Roof/ Building Drains at Manufacturing and Commercial Buildings

Description of Pollutant Sources: Stormwater runoff from roofs and sides of manufacturing and commercial buildings can be sources of pollutants caused by leaching of roofing materials, building vents, and other air emission sources. Vapors, entrained liquid, and solid droplets/particles have been identified as potential pollutants in roof/building runoff. Metals, solvents, acidic/alkaline pH, BOD, and organics are some of the pollutant constituents identified.

Pollutant Control Approach: Evaluate the potential sources of stormwater pollutants and apply source control BMPs where feasible.

Applicable Operational Source Control BMPs:

- If leachates and(or) emissions from buildings are suspected sources of stormwater pollutants, then sample and analyze the stormwater draining from the building.
- If a roof/building stormwater pollutant source is identified, implement appropriate source control measures such as air pollution control equipment, selection of materials, operational changes, material recycle, process changes, etc.

BMPs for Soil Erosion and Sediment Control at Industrial Sites

Description of Pollutant Sources: Industrial activities on soil areas, exposed and disturbed soils, steep grading, etc. can be sources of sediments that can contaminate stormwater runoff.

Pollutant Control Approach: Limit the exposure of erodible soil, stabilize or cover erodible soil where necessary to prevent erosion, and(or) provide treatment for stormwater contaminated with TSS caused by eroded soil.

Applicable BMPs: (see also Chapter 7)

Cover Practice Options:

- Vegetative cover, such as grass, trees, shrubs, on erodible soil areas;
- Covering with mats such as jute, synthetic fiber; and(or)
- Preservation of natural vegetation including grass, trees, shrubs, and vines

Structural Practice Options:

- Vegetated swale, dike, silt fence, check dam, gravel filter berm, sedimentation basin, and proper grading.

BMPs for Spills of Oil and Hazardous Substances

Description of Pollutant Sources: Owners or operators of facilities engaged in drilling, producing, gathering, storing, processing, transferring, distributing, refining, or consuming oil and(or) oil products are required by federal law to have a "Spill Prevention and Control Plan." A spill control plan is required if: the unburied oil storage capacity of the facility is 1,320 gallons or more, or any single container with a capacity in excess of 660 gallons, could reasonably be expected to discharge oil in harmful quantities, as defined in 40 CFR Part 110, into or upon the navigable waters of the United States or adjoining shorelines {40 CFR 112.1 (b)}. Onshore and offshore facilities that could not, due to their locations, reasonably be expected to discharge oil into or upon the navigable waters of the United States or adjoining shorelines are exempt from these regulations {40 CFR 112.1(1)(i)}. Owners of businesses that produce dangerous wastes are also required by state law to have a spill control plan. These businesses should refer to Appendix IV-D R.6 of the *Stormwater Management Manual for Western Washington*, Ecology Publication # 99-15, August 2001. The federal definition of "oil" is: oil of any kind or any form, including, but not limited to petroleum, fuel oil, sludge, oil refuse, and oil mixed with wastes other than dredged spoil.

Pollutant Control Approach: Maintain, update, and implement an oil spill prevention and cleanup plan.

Applicable Operational BMPs: The businesses and public agencies identified that are required to prepare and implement an Emergency Spill Cleanup Plan shall implement the following:

- Prepare an Emergency Spill Control Plan (SCP) that includes:
  - A description of the facility, including the owner's name and address;
  - The nature of the activity at the facility;
  - The general types of chemicals used or stored at the facility;
  - A site plan showing the location of storage areas for chemicals, the locations of storm drains, the areas draining to them, and the location and description of any devices to stop spills from leaving the site, such as positive control valves;
  - Cleanup procedures;
  - Notification procedures to be used in the event of a spill, such as notifying key personnel. Agencies such as Ecology, local fire department, Washington State Patrol, and the local jurisdiction, shall be notified; and

- The name of the designated person with overall spill cleanup and notification responsibility.

- Train key personnel in the implementation of the Emergency SCP. Prepare a summary of the plan and post it at appropriate points in the building, identifying the spill cleanup coordinators, location of cleanup kits, and phone numbers of regulatory agencies to be contacted in the event of a spill;
- Update the SCP regularly;
- Immediately notify Ecology and the local jurisdiction if a spill may reach sanitary or storm sewers, groundwater, or surface water, in accordance with federal and Ecology spill reporting requirements;
- Immediately clean up spills. Do not use emulsifiers for cleanup unless an appropriate disposal method for the resulting oily wastewater is implemented. Absorbent material shall not be washed down a floor drain or storm sewer; and,
- Locate emergency spill containment and cleanup kit(s) in high potential spill areas. The contents of the kit shall be appropriate for the type and quantities of chemical liquids stored at the facility.

Recommended Additional Operational BMP: Spill kits should include appropriately lined drums, absorbent pads, and granular or powdered materials for neutralizing acids or alkaline liquids, where applicable. In fueling areas, absorbent should be packaged in small bags for easy use and small drums should be available for storage of absorbent and(or) used absorbent. Spill kits should be deployed in a manner that allows rapid access and use by employees.

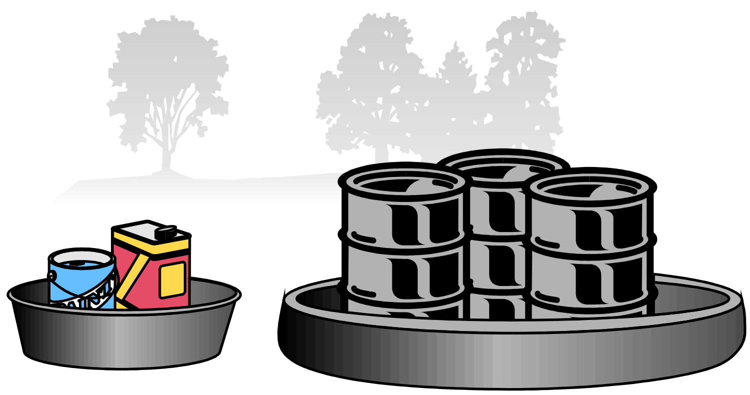

Figure 8.3.8 – Secondary Containment System

BMPs for Storage of Liquid, Food Waste, or Dangerous Waste Containers

Description of Pollutant Sources: Steel and plastic drums with volumetric capacities of 55 gallons or less are typically used at industrial facilities for container storage of liquids and powders. The BMPs specified below apply to container(s) located outside a building used for temporary storage of accumulated food wastes, vegetable or animal grease, used oil, liquid feedstock or cleaning chemical, or dangerous wastes (liquid or solid), unless the business is permitted by Ecology to store the wastes. Leaks and spills of pollutant materials during handling and storage are the primary sources of pollutants. Oil and grease, acid/alkali pH, BOD, COD are potential pollutant constituents.

Pollutant Control Approach: Store containers in impervious containment under a roof or other appropriate cover, or in a building. For roll-containers (for example, dumpsters) that are picked up directly by the collection truck, a filet can be placed on both sides of the curb to facilitate moving the dumpster. If a storage area is to be used on-site for less than 30 days, a portable temporary secondary system like that shown in Figure 8.3.8 can be used in lieu of a permanent system as described above.

Applicable Operational BMPs:

- Place tight-fitting lids on all containers.
- Place drip pans beneath all mounted container taps and at all potential drip and spill locations during filling and unloading of containers.
- Inspect container storage areas regularly for corrosion, structural failure, spills, leaks, overfills, and failure of piping systems. Check containers daily for leaks/spills. Replace containers, and replace and tighten bungs in drums, as needed.
- Businesses accumulating dangerous wastes that do not contain free liquids need only to store these wastes in a sloped designated area with the containers elevated or otherwise protected from stormwater run-on.

Drums stored in an area where unauthorized persons may gain access must be secured in a manner that prevents accidental spillage, pilferage, or any unauthorized use (see Figure 8.3.9).

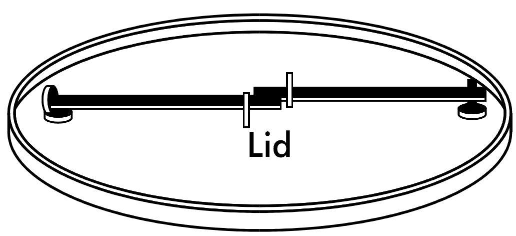

Figure 8.3.9 – Locking system for drum lid

- If the material is a dangerous waste, the business owner must comply with any additional Ecology requirements.
- Storage of reactive, ignitable, or flammable liquids must comply with the Uniform Fire Code.
- Cover dumpsters, or keep them under cover, such as a lean-to, to prevent the entry of stormwater. Replace or repair leaking garbage dumpsters.
- Drain dumpsters and(or) dumpster pads to sanitary sewer. Keep dumpster lids closed. Install waterproof liners.

Applicable Structural Source Control BMPs:

- Keep containers with dangerous waste, food waste, or other potential pollutant liquids inside a building, unless this is impracticable due to site constraints or Uniform Fire Code requirements.
- Store containers in a designated area, which is covered, bermed or diked, paved, and impervious, in order to contain leaks and spills (see Figure 8.3.10). The secondary containment shall be sloped to drain into a dead-end sump for the collection of leaks and small spills.
- For liquid wastes, surround the containers with a dike as illustrated in Figure 8.3.10. The dike must be of sufficient height to provide a volume of either: 10 percent of the total enclosed container volume or 110 percent of the volume contained in the largest container, whichever is greater, or, if a single container, 110 percent of the volume of that container.
- Where material is temporarily stored in drums, a containment system can be used as illustrated, in lieu of system above (see Figure 8.3.8).
- Place containers mounted for direct removal of a liquid chemical for use by employees inside a containment area as described above. Use a drip pan during liquid transfer (see Figure 8.3.11).

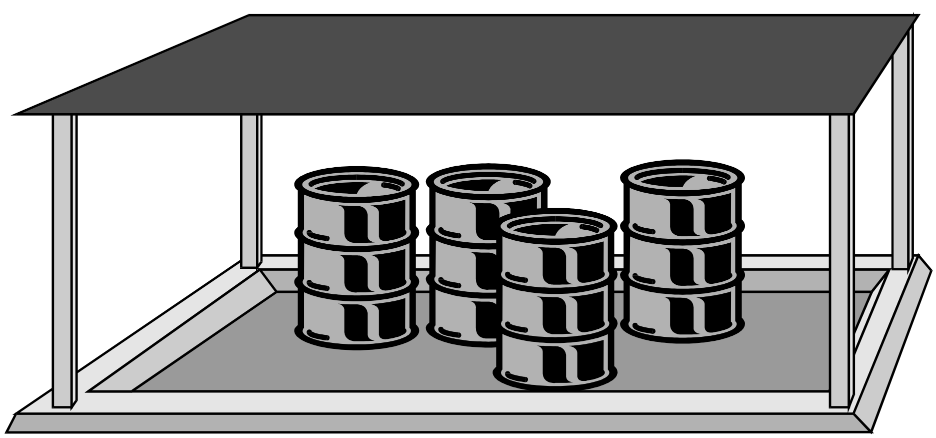

Figure 8.3.10 – Covered and bermed containment area

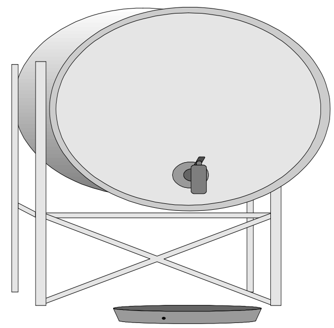

Figure 8.3.11 – Mounted container - with drip pan

Applicable Treatment BMP:

- For contaminated stormwater in the containment area, connect the sump outlet to a sanitary sewer, if approved by the local jurisdiction, or to appropriate treatment, such as an API or CP oil/water separator, catch basin filter or other appropriate system (see Chapter 5). Equip the sump outlet with a normally closed valve to prevent the release of spilled or leaked liquids, especially flammables (compliance with Fire Codes), and dangerous liquids. This valve may be opened only for the conveyance of contaminated stormwater to treatment.
- Another option for discharge of contaminated stormwater is to pump it from a dead-end sump or catchment to a tank truck or other appropriate vehicle for off-site treatment and(or) disposal.

BMPs for Storage of Liquids in Permanent Above-Ground Tanks

Description of Pollutant Sources: Above-ground tanks containing liquids (excluding uncontaminated water) may be equipped with a valved drain, vent, pump, and bottom hose connection. They may be heated with steam heat exchangers equipped with steam traps. Leaks and spills can occur at connections and during liquid transfer. Oil and grease, organics, acids, alkalis, and heavy metals in tank water and condensate drainage can also cause stormwater contamination at storage tanks.

Pollutant Control Approach: Install secondary containment or a double-walled tank. Slope the containment area to a drain with a sump. Stormwater collected in the containment area may need to be discharged to treatment such as an API or CP oil/water separator, or equivalent BMP. Add safeguards against accidental releases, including: protective guards around tanks to protect against vehicle or forklift damage, and tagging valves to reduce human error. Tank water and condensate discharges are process wastewater that may need an NPDES permit.

Applicable Operational BMPs:

- Inspect the tank containment areas regularly to identify problem components, such as fittings, pipe connections, and valves, for leaks/spills, cracks, corrosion, etc.

- Place adequately sized drip pans beneath all mounted taps and drip/spill locations during filling/unloading of tanks. Valved drain tubing may be needed in mounted drip pans.
- Sweep and clean the tank storage area regularly, if paved.
- Replace or repair tanks that are leaking, corroded, or otherwise deteriorating.
- All installations shall comply with the Uniform Fire Code and the National Electric Code.

Applicable Structural Source Control BMPs:

- Locate permanent tanks in impervious (Portland cement concrete or equivalent) secondary containment surrounded by dikes as illustrated in Figure 8.3.12, or UL approved double-walled. The dike must be of sufficient height to provide a containment volume of either 10 percent of the total enclosed tank volume or 110 percent of the volume contained in the largest tank, whichever is greater, or, if a single tank, 110 percent of the volume of that tank.
- Slope the secondary containment to drain to a dead-end sump (optional), or equivalent, for the collection of small spills.
- Include a tank overfill protection system to minimize the risk of spillage during loading.

Applicable Treatment BMPs:

- If the tank containment area is uncovered, equip the outlet from the spill-containment sump with a shutoff valve that is normally closed and may be opened, manually or automatically, only to convey contaminated stormwater to approved treatment or disposal or to convey uncontaminated stormwater to a storm drain. Evidence of contamination can include the presence of visible sheen, color, or turbidity in the runoff, or existing or historical operational problems at the facility. Simple pH measurements with litmus or pH paper can be used for areas subject to acid or alkaline contamination.
- At petroleum tank farms, convey stormwater contaminated with floating oil or debris in the contained area through an API or CP-type oil/water separator, or other approved treatment prior to discharge to storm drain or surface water.

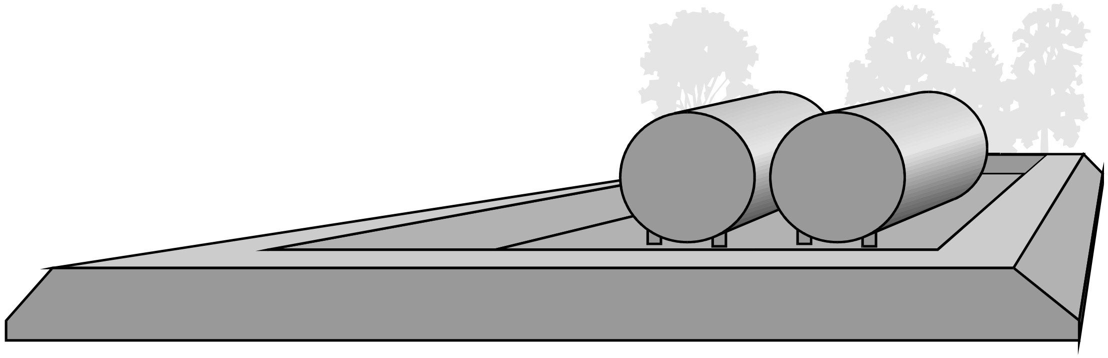

Figure 8.3.12 - Above-ground Tank Storage

BMPs for Storage or Transfer (Outside) of Solid Raw Materials, By-Products, or Finished Products

Description of Pollutant Sources: Solid raw materials, by-products, or products, such as gravel, sand, salts, topsoil, compost, logs, sawdust, wood chips, lumber and other building materials, concrete, and metal products, are typically stored outside in large piles, stacks, etc. at commercial or industrial establishments. Contact of outside bulk materials with stormwater can cause leachate and(or) erosion of the stored materials. Contaminants include TSS, BOD, organics, and dissolved salts (sodium, calcium, and magnesium chloride, etc).

Pollutant Control Approach: Provide impervious containment with berms, dikes, etc. and(or) cover to prevent run-on and discharge of leachate pollutant(s) and TSS.

Applicable Operational BMP: Do not hose down the contained stockpile area to a storm drain, or a conveyance to a storm drain, or to receiving water.

Applicable Structural Source Control BMP Options: Choose one or more of the source control BMP options listed below for stockpiles greater than five cubic yards of erodible or water soluble materials, such as soil, road deicing salts, compost, unwashed sand and gravel, sawdust, etc. Also included are outside storage areas for solid materials, such as logs, bark, lumber, metal products, etc.

- Store in a building or paved and bermed covered area as shown in Figure 8.3.13; or
- Place temporary plastic sheeting (polyethylene, polypropylene, hypalon, or equivalent) over the material as illustrated (see Figure 8.3.14); or
- Pave the area and install a stormwater drainage system. Place curbs or berms along the perimeter of the area to prevent the run-on of uncontaminated stormwater and to collect and convey runoff to treatment. Slope the paved area in a manner that minimizes the contact between stormwater (e.g., pooling) and leachable materials in compost, logs, bark, wood chips, etc.; or

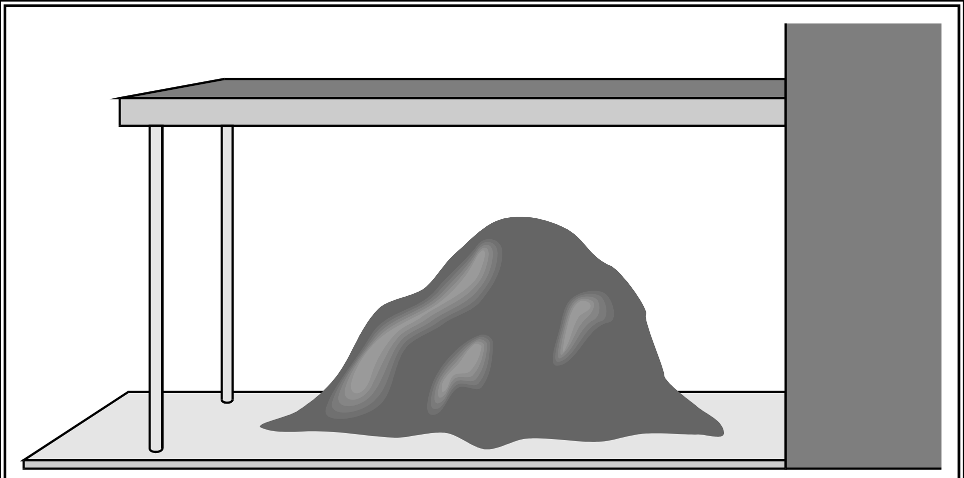

Figure 8.3.13 - Covered storage area for bulk solids (include berm if needed)

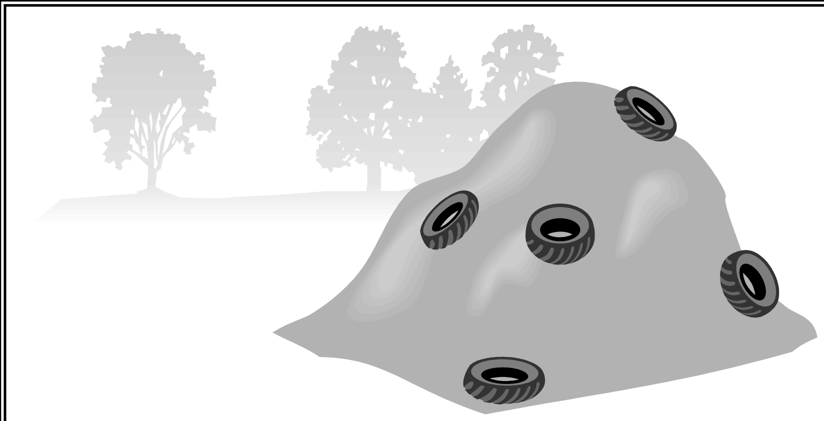

Figure 8.3.14 - Material covered with plastic sheeting

- For large stockpiles that cannot be covered, implement containment practices at the perimeter of the site and at any catch basins as needed to prevent erosion and discharge of the stockpiled material offsite or to a storm drain. Ensure that contaminated stormwater is not discharged directly to catch basins without conveying through a treatment BMP.

Applicable Treatment BMP: Convey contaminated stormwater from the stockpile area to a wet pond, wet vault, settling basin, media filter, or other appropriate treatment system depending on the contamination.

Recommended Additional Operational BMPs:

- Maintain drainage areas in and around storage of solid materials with a minimum slope of 1.5 percent to prevent pooling and to minimize leachate formation. Areas should be sloped to drain stormwater to the perimeter where it can be collected, or to internal drainage "alleyways" where material is not stockpiled.

- Sweep paved storage areas regularly for collection and disposal of loose solid materials.
- If and when feasible, collect and recycle water-soluble materials (leachates) to the stockpile.
- Stock cleanup materials, such as brooms, dustpans, and vacuum sweepers near the storage area.

BMPs for Urban Streets

Description of Pollutant Sources: Streets can be the sources of vegetative debris, paper, fine dust, vehicle liquids, tire wear residues, heavy metals (lead and zinc), soil particles, ice control salts, domestic wastes, lawn chemicals, and vehicle combustion products. Street surface contaminants have been found to contain significant concentrations of particle sizes less than 250 microns. (Sartor and Boyd, 1972)

Pollutant Control Approach: Conduct efficient street sweeping where and when appropriate to minimize the contamination of stormwater. Do not wash street debris into storm drains.

Recommended BMPs: (see also Chapters 5 and 6)

- For maximum stormwater pollutant reductions on curbed streets and high volume parking lots use efficient vacuum sweepers.

  High-efficiency street sweepers utilize strong vacuums and the mechanical action of main and gutter brooms combined with an air filtration system that only returns clean air to the atmosphere (i.e., filters very fine particulates). They sweep dry and use no water, since they do not emit any dust.

  It has been reported that high-efficiency vacuum sweepers have the capability of removing 80 percent or more of the accumulated street dirt particles whose diameters are less than 250 microns, from pavements under good condition (Sutherland, 1998). This assumes reasonably expected accumulation conditions and pavements that are in good condition.

- For moderate stormwater pollutant reductions on curbed streets use regenerative air sweepers or tandem sweeping operations.

  A tandem sweeping operation involves a single pass of a mechanical sweeper followed immediately by a single pass of a vacuum sweeper or regenerative air sweeper.

  A regenerative air sweeper blows air down on the pavement to entrain particles and uses a return vacuum to transport the material to the hopper. These operations usually use water to control dust. This reduces their ability to pick up fine particulates.

  It has been reported that these types of sweepers have the capability of removing approximately 25 to 50 percent of the accumulated street dirt particles whose diameters are less than 250 microns (Sutherland, 1998). This assumes typical accumulation conditions and pavements that are in good condition.

- For minimal stormwater pollutant reductions on curbed streets use mechanical sweepers.

  Mechanical sweepers are referred to as broom sweepers and use the mechanical action of main and gutter brooms to throw material on a conveyor belt that transports it to the hopper. These sweepers usually use water to control dust. This reduces their ability to pick up fine particulates.

  It has been reported that mechanical sweepers have the capability of removing only 10 to 20 percent of the accumulated street dirt particles whose diameters are less than 250 microns (Sutherland, 1998). This assumes the most favorable accumulation conditions and that pavements are in good condition.

- Conduct sweeping at optimal frequencies. Optimal frequencies are those scheduled sweeping intervals that produce the most cost-effective annual reduction of pollutants normally found in stormwater and can vary depending on land use, traffic volume, and rainfall patterns.
- Train operators in those factors that result in optimal pollutant removal. These factors include sweeper speed, brush adjustment and rotation rate, sweeping pattern, maneuvering around parked vehicles, and interim storage and disposal methods.
- Consider the use of periodic parking restrictions in low to medium density single-family residential areas to ensure the sweeper's ability to sweep along the curb.
- Establish programs for prompt sweeping, removal, and disposal of debris from special events that will generate higher than normal loadings.
- Inform citizens about eliminating yard debris, oil and other wastes in street gutters to reduce street pollutant sources.

BMPs to Consider: High-efficiency street sweepers utilize strong vacuums and the mechanical action of main and gutter brooms combined with an air filtration system that only returns clean air to the atmosphere (i.e., filters very fine particulates). They sweep dry and use no water since they do not emit any dust.

It has been reported that high-efficiency vacuum sweepers have the capability of removing, from pavements under good condition, 80 percent or more of the accumulated street dirt particles whose diameters are less than 250 microns (Sutherland, 1998). This assumes reasonably expected accumulation conditions and that pavements are in good condition.

BMPs for Washing and Steam Cleaning Vehicles/ Equipment/ Building Structures

Description of Pollutant Sources: Vehicles, aircraft, vessels, and transportation; restaurant cooking, carpet cleaning, and industrial equipment; and large buildings may be commercially cleaned with low or high pressure water or steam. This includes frequent "charity" car washes at gas stations and commercial parking lots. The cleaning can include hand washing, scrubbing, sanding, etc. Wash water from cleaning activities can contain oil and grease, suspended solids, heavy metals, soluble organics, soaps, and detergents that can contaminate stormwater.

Pollutant Control Approach: The preferred approach is to cover and(or) contain the cleaning activity, or conduct the activity inside a building, to separate the uncontaminated stormwater from the pollutant sources. Wash water must be conveyed to a sanitary sewer after approval by the local jurisdiction, temporarily stored before proper disposal, or recycled, with no discharge to the ground, to a storm drain, or to surface water. Wash water may be discharged to the ground after proper treatment in accordance with Ecology guidance WQ-95-056, "Vehicle and Equipment Wash water Discharges," June 1995. The quality of any discharge to the ground after proper treatment must comply with Ecology's groundwater quality standards, Chapter 173-200 WAC. Contact the local Ecology regional office for an NPDES permit application for discharge of wash water to surface water or to a storm drain after on-site treatment.

Applicable Structural Source Control BMPs: Conduct vehicle/ equipment washing in one of the following locations:

- At a commercial washing facility in which the washing occurs in an enclosure and drains to the sanitary sewer, or
- In a building constructed specifically for washing of vehicles and equipment, which drains to a sanitary sewer.

Conduct outside washing operation in a designated wash area with the following features:

- In a paved area, constructed as a spill containment pad to prevent the run-on of stormwater from adjacent areas. Slope the spill containment area so that wash water is collected in a containment pad drain system with perimeter drains, trench drains, or catchment drains. Size the containment pad to extend out a minimum of four feet on all sides of the vehicles and(or) equipment being washed.
- Convey the wash water to a sump (like a grit separator) and then to a sanitary sewer (if allowed by the local jurisdiction), or other appropriate wastewater treatment or recycle system. An NPDES permit may be required for any wash water discharge to a storm drain or receiving water after treatment. Contact the Ecology regional office for NPDES permit requirements.
- The containment sump must have a positive control outlet valve for spill control with live containment volume and oil/water separation.

Size the minimum live storage volume to contain the maximum expected daily wash water flow plus the sludge storage volume below the outlet pipe. The outlet valve will be shut during the washing cycle to collect the wash water in the sump. The valve should remain shut for at least two hours following the washing operation to allow the oil and solids to separate before discharge to a sanitary sewer. (See Ecology Publication WQ-95-056).

The purpose of the valve is to convey only wash water and contaminated stormwater to a treatment system.

- The inlet valve in the discharge pipe should be closed when washing is not occurring, thereby preventing the entry of uncontaminated stormwater into the pretreatment/treatment system. The stormwater can then drain into the conveyance/discharge system outside of the wash pad (essentially bypasses the wash water treatment/conveyance system). Post signs to inform people of the operation and purpose of the valve. Clean the concrete pad thoroughly until there is no foam or visible sheen in the wash water prior to closing the inlet valve and allowing uncontaminated stormwater to overflow and drain off the pad. (See Figure 8.3.15)
- Collect the wash water from building structures and convey it to appropriate treatment, such as a sanitary sewer system, where feasible, if it contains oils, soaps, or detergents. If the wash water does not contain oils, soaps, or detergents then it could drain to soils that have sufficient natural attenuation capacity for dust and sediment.

Recommended Additional BMPs:

- The wash area should be well marked at gas stations, multi-family residences, and any other business where non-employees wash vehicles.
- For uncovered wash pads, the positive control outlet valve may be manually operated, but a pneumatic or electric valve system is preferable. The valve may be on a timer circuit where it is opened upon completion of a wash cycle. The timer would then close the valve after the sump or separator is drained (Figure 8.3.15).
- Use phosphate-free biodegradable detergents when practicable.
- Consider recycling the wash water.
- Because soluble/emulsifiable detergents can be used in the wash medium, the selection of soaps and detergents and treatment BMPs should be considered carefully. Oil/water separators are ineffective in removing emulsified or water soluble detergents.

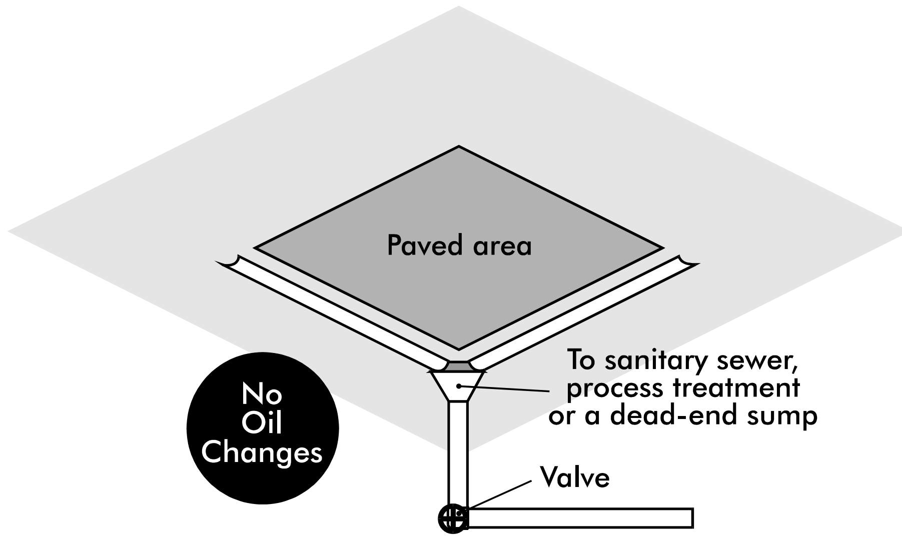

Figure 8.3.15 – Uncovered Wash Area

Exceptions:

- At gas stations (for charity car washes) or commercial parking lots, where it is not possible to discharge the wash water to a sanitary sewer, a temporary plug or a temporary sump pump can be used at the storm drain to collect the wash water for off-site disposal, such as to a nearby sanitary sewer.
- New and used car dealerships may wash vehicles in the parking stalls, as long as a temporary plug system is used, to collect the wash water for disposal as stated above, or an approved treatment system for the wash water is in place.

At industrial sites, contact the local Ecology regional office for NPDES permit requirements, even if soaps, detergents, and(or) other chemical cleaners are not used in washing trucks.

BMPs for Wood Treatment Areas

Description of Pollutant Sources: Wood treatment includes both anti-staining and wood preserving using pressure processes or by dipping or spraying. Wood preservatives include creosote, creosote/coal tar, pentachlorophenol, copper naphthenate, arsenic trioxide, malathion, or inorganic arsenicals, such as chromated copper arsenate, acid copper chromate, chromate zinc chloride, and fluor-chrome-arsenate-phenol. Anti-staining chemical additives include iodo-prophenyl-butyl carbamate, dimethyl sulfoxide, didecyl dimethyl ammonium chloride, sodium azide, 8-quinolinol, copper (II) chelate, sodium ortho-phenylphenate, 2-(thiocyanomethylthio)-benzothiazole (TCMTB) and methylene bis-(thiocyanate), and zinc naphthenate.

Pollutant sources include: drips of condensate or preservative after pressurized treatment; product wash water (in the treatment or storage areas), spills and leaks from process equipment and preservative tanks; fugitive emissions from vapors in the process, blowouts and emergency pressure releases; and kick-back from lumber (phenomenon where preservative leaks as it returns to normal pressure). Potential pollutants typically include the wood treating chemicals, BOD, suspended solids, oil and grease, benzene, toluene, ethylbenzene, phenol, chlorophenols, nitrophenols, heavy metals, and PAH depending on the chemical additive used.

Pollutant Control Approach: Cover and contain all wood treating areas and prevent all leaching of and stormwater contamination by wood treating chemicals. All wood treating facilities in Washington State are required to be covered under an individual NPDES permit.

Applicable Operational BMPs: The individual NPDES permit will require at a minimum the following operational BMPs.

- Dedicate equipment that is used for treatment activities to prevent the tracking of treatment chemicals to other areas on the site.
- Eliminate non-process traffic on the drip pad. Scrub down non-dedicated lift trucks on the drip pad.
- Immediately remove and properly dispose of soils with visible surface contamination (green soil) to prevent the spread of chemicals to groundwater and(or) surface water via stormwater runoff.
- If any wood is observed to be contributing chemicals to the environment in the treated wood storage area, relocate it on a concrete chemical containment structure until the surface is clean and until it is drip free and surface dry.

Recommended Operational BMP: Consider using preservative chemicals that do not adversely impact receiving surface water and groundwater.

Applicable Structural Source Control BMPs: The individual NPDES permit will require at a minimum the following structural source control BMPs:

- Cover and(or) enclose, and contain with impervious surfaces all wood treatment areas. Slope and drain areas around dip tanks, spray booths, retorts, and any other process equipment in a manner that allows return of treatment chemicals to the wood treatment process.
- Cover storage areas for freshly treated wood to prevent contact of treated wood products with stormwater. Segregate clean stormwater from process water. Ensure that all process water is conveyed to an approved treatment system.

- Seal any holes or cracks in the asphalt areas that are subject to wood treatment chemical contamination.
- Elevate stored, treated wood products to prevent contact with stormwater run-on and runoff.
- Place dipped lumber over the dip tank, or on an inclined ramp for a minimum of 30 minutes to allow excess chemical to drip back to the dip tank.
- Place treated lumber either from dip tanks or retorts in a covered paved storage area for at least 24 hours before placement in outside storage. Use a longer storage period during cold weather unless the temporary storage building is heated. The wood shall be drip free and surface dry before it is moved outside.

Appendix 8A – Urban Land Uses and Pollutant Generating Sources

Use this section to identify pollutant-generating sources at various land uses (manufacturing, transportation, communication, wholesale, retail, service - based on the 1987 Standard Industrial Classification codes (OMB, 1987), and public agencies). Applicable operational and structural source control, and treatment BMPs for each pollutant source can then be selected by referring to Section 8.3. Other land uses not included in this section should also consider implementing applicable BMPs for their pollutant sources.

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Manufacturing Businesses

Cement
SIC: 3241

Description: These businesses produce Portland cement, the binder used in concrete for paving, buildings, pipe, and other structural products. The three basic steps in cement manufacturing are: 1) proportioning, grinding, and blending raw materials; 2) heating raw materials to produce a hard, stony substance known as clinker; and 3) combining the clinker with other materials and grinding the mixture into a fine powdery form. The raw materials include limestone, silica, alumina, iron, chalk, oyster shell marl, or shale. Waste materials from other industries are often used, such as slag, fly ash, and spent blasting sand. Raw materials are crushed, mixed, and heated in a kiln to produce the correct chemical composition. Kilns typically are coal, gas, or oil fired. The output of the kiln is a clinker that is ground to produce the final product.

The basic process may be wet or dry. In the wet process water is mixed with the raw ingredients in the initial crushing operation and in some cases is used to wash the material prior to use. Water may also be used in the air pollution control scrubber. The most significant waste material from cement production is the kiln dust. Concrete products may also be produced at ready-mix concrete facilities. Refer to "Concrete Products" for a description of the BMPs appropriate to these activities.

Potential Pollutant Generating Sources: Stormwater may be contaminated during the crushing, grinding, storage, and handling of kiln dust, limestone, shale, clay, coal, clinker, gypsum, anhydrite, slag, sand, and product; and at the vehicle and equipment maintenance, fueling, and cleaning areas. Total suspended solids, aluminum, iron and other heavy metals, pH, COD, potassium, sulfate, and oil and grease are some of the potential pollutants. The following mean concentrations in stormwater discharges have been reported on the U.S. Environmental Protection Agency's multi-sector permit fact sheet (EPA, 1995): TSS=1067, COD=107.5, aluminum=72.6, iron=7.5, all in mg/L, and pH=2-12. These values may be useful in characterizing stormwater contaminants at cement manufacturing facilities.

Chemicals Manufacturing
SIC: 2800, 3861

Description: This group is engaged in the manufacture of chemicals, or products based on chemicals, such as acids, alkalis, inks, chlorine, industrial gases, pigments, chemicals used in the production of synthetic resins, fibers and plastics, synthetic rubber, soaps and cleaners, pharmaceuticals, cosmetics, paints, varnishes, resins, photographic materials, chemicals, organic chemicals, agricultural chemicals, adhesives, sealants, and ink.

Potential Pollutant Generating Sources: Activities that can contaminate stormwater include bagging, blending, packaging, crushing, milling, shredding, granulation, grinding, storage, distribution, loading/unloading, and processing of materials; equipment storage; application of fertilizers; foundries; lime application; use of machinery; material handling and warehousing; cooling towers; fueling; boilers; hazardous waste treatment, storage and disposal; wastewater treatment; plant yard areas of past industrial activity; access roads and tracks; drum washing; and maintenance and repair.

Chemical businesses in the Seattle area surveyed for Dangerous Wastes have been found to produce waste caustic solutions, soaps, heavy metal solutions, inorganic and organic chemicals, solvents, acids, alkalis, paints, varnishes, pharmaceuticals, and inks. The potential pollutants include BOD, TSS, COD, oil and grease, pH, total phosphorus, nitrates, nitrites, total Kjeldahl nitrogen, ammonia, specific organics, and heavy metals. EPA stormwater multi-sector permit fact sheet data (7) includes the following mean values in mg/L except pH: BOD, 4.4-143.2; TSS, 35-493; COD, 42.36-245.3; Oil and Grease, 0.3-6.0; NO2+NO3, 0.3-35.9; TKN, 1.3-108.9; total P, 0.1-65.7; ammonia, 40.45-73.22; Al, 1.20-1.78; Cu, .12-19; Mn, .56-. 71; Zn, 1.74-2.11; Fe, 2.24-3.52; and pH, 3.5-10.4. This data could be helpful in characterizing stormwater pollutants at the facility.

Concrete Products SIC: 3270

Description: Businesses that manufacture ready-mix concrete, gypsum products, concrete blocks and bricks, concrete sewer or drainage pipe, septic tanks, and prestressed concrete building components. Concrete is prepared on site and poured into molds or forms to produce the desired product. The basic ingredients of concrete are sand, gravel, Portland cement, crushed stone, clay, and reinforcing steel for some products. Admixtures, including fly ash, calcium chloride, triethanolamine, lignosulfonic acid, sulfonated hydrocarbon, fatty acid glyceride, or vinyl acetate, may be added to obtain desired characteristics such as slower or more rapid curing times.

The first stage in the manufacturing process is proportioning cement, aggregate, admixtures and water, and then transporting the product to a rotary drum, or pan mixer. The mixture is then fed into an automatic block-molding machine that rams, presses, or vibrates the mixture into its final form. The final product is then stacked on iron framework cars where it cures in four hours. After being mixed in a central mixer, concrete is molded in the same manner as concrete block. The concrete cures in the forms for a number of hours. Forms are washed for reuse, and the concrete products are stored until they can be shipped.

Potential Pollutant Generating Sources: Pollutant generating activities/sources include stockpiles; washing of waste concrete from trucks, forms, equipment, and the general work area; and water from the curing of concrete products. Besides the basic ingredients for making concrete products, chemicals used in the curing of concrete and the removal of forms may end up in stormwater. These chemicals can include latex sealants, bitumastic coatings, and release agents. Trucks and equipment maintained on site may generate waste oil and solvents, and other waste materials. Potential pollutants include TSS, COD, BOD, pH, lead, iron, zinc, and oil and grease.

Electrical Products SIC: 3600, 3800

Description: A variety of products are produced including electrical transformers and switchgear, motors, generators, relays, and industrial controls; communications equipment for radio and TV stations and systems; electronic components and accessories including semiconductors; printed board circuits; electromedical and electrotherapeutic apparatus; and electrical instrumentation. Manufacturing processes include electroplating, machining, fabricating, etching, sawing, grinding, welding, and parts cleaning. Materials used include metals, ceramics, quartz, silicon, inorganic oxides, acids, alkaline solutions, arsenides, phosphides, cyanides, oils, fuels, solvents, and other chemicals.

Potential Pollutant Generating Sources: Pollutant generating activities/sources include bulk storage of raw materials, by-products or finished products; loading and unloading of liquid materials from truck or rail; temporary storage of waste oil and solvents from cleaning manufacturing equipment; used equipment temporarily stored on site that could drip oil and residual process materials; maintenance and repair of vehicles and equipment; and temporary storage of dangerous wastes.

Waste liquids which are sometimes stored outside include spent acetone and solvents, ferric chloride solutions, soldering fluxes mixed with thinner or alcohol, spent acids, and oily waste. Several of these liquid wastes contain chlorinated hydrocarbons, ammonium salts, and metals, such as chromium, copper, lead, silver, zinc, nickel, and tin. Waste solids include soiled rags and sanding materials.

Wastewater consists of solutions and rinses from electroplating operations, and the wastewaters from cleaning operations. Water may also be used to cool saws and grinding machines. Sludges are produced by the wastewater treatment process. Potential pollutants include TSS, oil and grease, organics, pH, BOD, COD, total Kjeldahl nitrogen, nitrate and nitrite nitrogen, copper, zinc, lead, and silver.

Food Products SIC: 2000

Description: Businesses in this category include meat packing plants, poultry slaughtering and processing, sausage and prepared meats, dairy products, preserved fruits and vegetables, flour, bakery products, sugar and confectioneries, vegetable and animal oils, beverages, canned, frozen or fresh fish, pasta products, snack foods, and manufactured ice. Food processing typically occurs inside buildings. Exceptions are meat packing plants where live animals may be kept outside, and fruit and vegetable plants where the raw material may be temporarily stored outside. Meat production facilities include stockyards, slaughtering, cutting and deboning, meat processing, rendering, and materials recovery. Dairy production facilities include receiving stations, clarification, separation, and pasteurization followed by culturing, churning, pressing, curing, blending, condensing, sweetening, drying, milling, and packaging.

Canned frozen and preserved fruits and vegetables are typically produced by washing, cutting, blanching, and cooking followed by drying, dehydrating, and freezing.

Grain mill products are processed during washing, milling, debranning, heat treatment, screening, shaping, and vitamin and mineral supplementing. Bakery products processing includes mixing, shaping, of dough; cooling; and decorating. Operations at an edible oil manufacturer include refining, bleaching, hydrogenation, fractionation, emulsification, deodorization, filtration, and blending. Beverage production includes brewing, distilling, fermentation, blending, and packaging. Wine processors often crush grapes outside the process building and(or) store equipment outside when not in use. Some wine producers use juice from grapes crushed elsewhere. Some vegetable and fruit processing plants use caustic solutions.

Potential Pollutant Generating Sources: The following are potential stormwater pollutant causing activities/sources: loading/unloading of materials, equipment/vehicle maintenance, liquid storage in tanks and drums, air emissions (ovens, vents), solid wastes handling and storage, wastewater treatment, pest control, animal containment and transit, and vegetable storage. Materials exposed to stormwater include acids, ammonia, activated carbon, bleach, blood, bone meal, brewing residuals, caustic soda, chlorine, coke oven tar, detergents, eggs, feathers, feed, ferric chloride, fruits, vegetables, coffee beans, gel bone, grain, hides, lard, manure, milk, salts, skim powder, starch, sugar, tallow, ethyl alcohol, oils, fats, whey, yeast, and wastes. The following are the pollutants typically expected from this industry segment: BOD, TSS, Oil and Grease, pH, Kjeldahl nitrogen, copper, manganese, fecal coliform, and pesticides.

Glass Products SIC: 3210, 3220, 3230

Description: The glass form produced may be flat or window, safety, or container; tubing; glass wool; or fibers. The raw materials are sand mixed with a variety of oxides, such as aluminum, antimony, arsenic, lead, copper, cobalt oxide, and barium. The raw materials are mixed and heated in a furnace. Processes that vary with the intended product shape the resulting molten material. The cooled glass may be edged, ground, polished, annealed, and(or) heat-treated to produce the final product. Air emissions from the manufacturing buildings are scrubbed to remove particulates.

Potential Pollutant Generating Sources: Raw materials are generally stored in silos, except for crushed recycled glass and materials washed off recycled glass. Contamination of stormwater and(or) groundwater can be caused by raw materials lost during unloading operations, errant flue dust, equipment/vehicle maintenance, and engine fluids from mobile lifting equipment that is stored outside. The maintenance of the manufacturing equipment will produce waste lubricants and cleaning solvents. The flue dust is likely to contain heavy metals, such as arsenic, cadmium, chromium, mercury, and lead. Potential pollutants include suspended solids, oil and grease, high/low pH, and heavy metals, such as arsenic, cadmium, chromium, mercury, and lead.

Industrial Machinery and Equipment, Trucks and Trailers, Aircraft, Aerospace, and Railroad SIC: 3500, 3713/14, 3720, 3740, 3760, 3800

Description: This category includes the manufacture of a variety of equipment, including engines and turbines, farm and garden equipment, construction and mining machinery, metal working machinery, pumps, computers and office equipment, automatic vending machines, refrigeration and heating equipment, and equipment for the manufacturing industries. This group also includes many small machine shops; and the manufacturing of trucks, trailers and parts, airplanes and parts, missiles, spacecraft, and railroad equipment and instruments.

Manufacturing processes include various forms of metal working and finishing, such as electroplating, anodizing, chemical conversion coating, etching, chemical milling, cleaning, machining, grinding, polishing, sand blasting, laminating, hot dip coating, descaling, degreasing, paint stripping, painting, and the production of plastic and fiberglass parts. Raw materials include ferrous and non-ferrous metals, such as aluminum, copper, iron, steel, and their alloys; paints, solvents, acids, alkalis, fuels, lubricating and cutting oils; and plastics.

Potential Pollutant Generating Sources: Potential pollutant sources include fuel islands, maintenance shops, loading/unloading of materials, and outside storage of gasoline, diesel, cleaning fluids, equipment, solvents, paints, wastes, detergents, acids, other chemicals, oils, metals, and scrap materials. Air emissions from stacks and ventilation systems are potential areas for exposure of materials to rain water.

Metal Products SIC: 2514, 2522, 2542, 3312, 3314-17, 3320, 3350, 3360, 3400, 3590

Description: This group includes mills that produce basic metals and primary products, as well as foundries, electroplaters, and fabricators of final metal products. Basic metal production includes steel, copper, and aluminum. Mills that transform metal billets, either ferrous or nonferrous, such as aluminum, to primary metal products are included. Primary metal forms include sheets, flat bar, building components, such as columns, beams and concrete reinforcing bar, and large pipe.

Steel mills in the Pacific Northwest use recycled metal and electric furnaces. The molten steel is cast into billets or ingots that may be reformed on site or taken to rolling mills that produce primary products. As iron and steel billets may sit outside before reforming, surface treatment to remove scale may occur prior to reforming. Foundries pour or inject molten metal into a mold to produce a shape that cannot be readily formed by other processes. The metal is first melted in a furnace. The mold is made of sand or metal die blocks that are locked together to make a complete cavity. The molten metal is ladled in and the mold is cooled. The rough product is finished by quenching, cleaning, and chemical treatment. Quenching involves immersion in a plain water bath or water with an additive.

Businesses that fabricate metal products from metal stock provide a wide range of products. The raw stock is manipulated in a variety of ways, including machining of various types, grinding, heating, shearing, deformation, cutting and welding, soldering, sand blasting, brazing, and laminating. Fabricators may first clean the metal by sand blasting, de-scaling, or solvent degreasing. Final finishing may involve electroplating, painting, or direct plating by fusing or vacuum metalizing.

Raw materials, in particular recycled metal, are stored outside prior to use, as are billets before reforming. The de-scaling process may use salt baths, sodium hydroxide, or acid (pickling).

Primary products often receive a surface coating treatment. Prior to the coating, the product surface may be prepared by acid pickling to remove scale, or alkaline cleaning to remove oils and greases. The two major classes of metallic coating operations are hot and cold coating. Zinc, tin, and aluminum coatings are applied in molten metal baths. Tin and chromium are usually applied electrolytically from plating solutions.

Potential Pollutant Generating Sources: Potential pollutant generating sources include: outside storage of chemicals, metal feedstock, byproducts (fluxes), finished products, fuels, lubricants, waste oil, sludge, waste solvents, dangerous wastes, piles of coal, coke, dusts, fly ash, baghouse waste, slag, dross, sludges, sand refractory rubble, and machining waste; unloading of chemical feedstock and loading of waste liquids, such as spent pickle liquor by truck or rail; material handling equipment, such as cranes, conveyors, trucks, and forklifts; particulate emissions from scrubbers, baghouses or electrostatic precipitators; fugitive emissions; maintenance shops; erosion of soil from plant yards; and floor, sink, and process wastewater drains.

Based on EPA's multi-sector industrial stormwater permit/fact sheet the following are ranges of mean composite/grab pollutant concentrations from this industrial group (values are in mg/L except pH): BOD at 34.1/32.2; COD at 109.8/221.3; NO2+NO3 N at 1.38/1.17; TKN at 3.05/3.56; Oil and grease at 8.88 (grab); pH at 2.6-10.3 (range-grab); total phosphorus at .52/1.25; TSS at 162/368; copper at 2.28/3.53; lead at 0.19/0.79; zinc at 6.60/8.90; aluminum at 2.6/4.8; iron at 32.30/45.97; cadmium at 0.015/0.074; chromium at 2.2/5.053; nickel at 0.75/0.7; manganese at 0.59/0.68; ammonia at 0.55/0.85; and pyrene at 0.01/0.06.

Paper and Pulp SIC: 2610, 2620, 2630

Description: Large industrial complexes in which pulp, and(or) paper, and(or) paperboard are produced. Products also include: newsprint, bleached paper, glassine, tissue paper, vegetable parchment, and industrial papers. Raw materials include: wood logs, chips, waste paper, jute, hemp, rags, cotton linters, bagasse, and esparto. The chips for pulping may be produced on site from logs, and(or) imported.

The following manufacturing processes are typically used: raw material preparation, pulping, bleaching, and papermaking. All of these operations use a wide variety of chemicals, including: caustic soda, sodium and ammonium sulfites, chlorine, titanium oxide, starches, solvents, adhesives, biocides, hydraulic oils, lubricants, dyes, and many chemical additives.

Potential Pollutant Generating Sources: The large process equipment used for pulping is not enclosed. Thus, precipitation falling over these areas may become contaminated. Maintenance of the process equipment produces waste products similar to that produced from vehicle and mobile equipment maintenance. Logs may be stored, debarked and chipped on site. Large quantities of chips are stored outside. Although this can be a source of pollution, the volume of stormwater flow is relatively small because the chip pile retains the majority of the precipitation. Mobile equipment such as forklifts, log stackers, and chip dozers are sources of leaks/spills of hydraulic fluids. Vehicles and equipment are fueled and maintained on site.

Paper Products
SIC: 2650, 2670

Description: Included are businesses that take paper stock and produce basic paper products, such as cardboard boxes and other containers, and stationery products, such as envelopes and bond paper. Wood chips, pulp, and paper can be used as feedstock.

Potential Pollutant Generating Sources:

- Outside loading/unloading of solid and liquid materials.
- Outside storage and handling of dangerous wastes, and other liquid and solid materials.
- Maintenance and fueling activities.
- Outside processing activities comparable to Pulp and Paper processing in preceding section.

Petroleum Products
SIC: 2911, 2950

Description: The petroleum refining industry manufactures gasoline, kerosene, distillate and residual oils, lubricants and related products from crude petroleum, asphalt paving, and roofing materials. Although petroleum is the primary raw material, petroleum refineries also use other materials, such as natural gas, benzene, toluene, chemical catalysts, caustic soda, and sulfuric acid. Wastes may include filter clays, spent catalysts, sludges, and oily water.

Asphalt paving products consist of sand, gravel and petroleum-based asphalt that serves as the binder. Raw materials include stockpiles of sand and gravel and asphalt emulsions stored in aboveground tanks.

Potential Pollutant Generating Sources:

- Outside processing such as distillation, fractionation, catalytic cracking, solvent extraction, coking, desulfuring, reforming, and desalting.
- Petrochemical and fuel storage and handling.

- Outside liquid chemical piping and tankage.
- Mobile liquid handling equipment, such as tank trucks, forklifts, etc.
- Maintenance and parking of trucks and other equipment.
- Waste piles, handling, and storage of asphalt emulsions, cleaning chemicals, and solvents.
- Waste treatment and conveyance systems.

The following are potential pollutants at oil refineries: oil and grease, BOD5, COD, TOC, phenolic compounds, PAH, ammonia nitrogen, TKN, sulfides, TSS, low and high pH, and chromium (total and hexavalent).

Printing
SIC: 2700

Description: This industrial category includes the production of newspapers, periodicals, commercial printing materials, and businesses that do their own printing and those that perform services for the printing industry, for example bookbinding. Processes include typesetting, engraving, photoengraving, and electrotyping.

Potential Pollutant Generating Sources: Various materials used in modifying the paper stock include inorganic and organic acids, resins, solvents, polyester film, developers, alcohol, vinyl lacquer, dyes, acetates, and polymers. Waste products may include waste inks and ink sludge, resins, photographic chemicals, solvents, acid and alkaline solutions, chlorides, chromium, zinc, lead, spent formaldehyde, silver, plasticizers, and used lubricating oils. As the printing operations occur indoors, the only likely points of potential contact with stormwater are the outside temporary storage of waste materials, offloading of chemicals at external unloading bays, and vehicle/equipment repair and maintenance. Pollutants of concern include TSS, pH, heavy metals, oil and grease, and COD.

Rubber and
Plastic Products
SIC: 3000

Description: Although different in basic feedstock and processes used, businesses that produce rubber, fiberglass, and plastic products belong to the same SIC group. Products in this category include: rubber tires, hoses, belts, gaskets, seals; and plastic sheet, film, tubes, pipes, bottles, cups, ice chests, packaging materials, and plumbing fixtures. The rubber and plastics industries use a variety of processes ranging from polymerization to extrusion, using natural or synthetic raw materials. These industries use natural or synthetic rubber, plastics components, pigments, adhesives, resins, acids, caustic soda, zinc, paints, fillers, and curing agents.

Potential Pollutant Generating Sources: Pollutant generating sources/activities include: storage of liquids, other raw materials or by-products, scrap materials, oils, solvents, inks and paints; unloading of liquid materials from trucks or rail cars; washing of equipment; waste oil and solvents produced by cleaning manufacturing equipment; used equipment that could drip oil and residual process materials; and maintenance shops.

Based on data in EPA's multi-sector permit fact sheet, the following are mean pollutant concentrations in mg/L, except for pH (unitless) and 1,1,1 trichloroethane, methylene chloride, toluene, zinc, oil/grease that are minimum-maximum grab sample values: BOD at 11.21-13.92, COD at 72.08-100.0, NO3 + NO2 Nitrogen at 86-1.26, TKN at 1.55-2.34, total phosphorus at .34-.41, TSS at 119.32-188.55, pH range of 2.56-10.1, trichloroethane at 0.00-0.38, methylene chloride at 0.00-13.0, toluene at 0.00-3.8, zinc at .011-7.60 and oil and grease at 0.0-91.0. These data may be helpful in characterizing potential stormwater pollutants.

Ship and Boat Building and Repair Yards SIC: 3730

Description: Businesses that build or repair ships and boats. Typical activities include: hull scraping, sandblasting, finishing, metal fabrication, electrical repairs, engine overhaul, welding, fiberglass repairs, hydroblasting, and steam cleaning.

Potential Pollutant Generating Sources: Outside boatyard activities that can be sources of stormwater pollution include pressure washing, surface preparation, paint removal, sanding, painting, engine/vessel maintenance and repairs, and material handling and storage.

Secondary sources of stormwater contaminants are cooling water, pump testing, gray water, sanitary waste, washing down the work area, and engine bilge water. Engine room bilge water and oily wastes are typically collected and disposed of through a licensed contracted disposal company. Two prime sources of copper are leaching of copper from anti-fouling paint and wastes from hull maintenance. Wastes generated by boatyard activities include: spent abrasive grits, spent solvent, spent oils, fuel, ethylene glycol, wash water, paint overspray, various cleaners/detergents and anti-corrosive compounds, paint chips, scrap metal, welding rods, wood, plastic, resins, glass fibers, dust, and miscellaneous trash, such as paper and glass.

Ecology, local shipyards, and METRO have sampled pressure wash wastewater. The effluent quality has been variable and frequently exceeds water quality criteria for copper, lead, tin, and zinc. From monitoring results received to date, metal concentrations typically range from 5 to 10 mg/L, but have gone as high as 190 mg/L copper with an average 55 mg/L copper.

Wood SIC 2420, 2450, 2434, 2490, 2511/12, 2517, 2519, 2521, 2541

Description: This group includes sawmills and all businesses that make wood products using cut wood, with the exception of wood treatment businesses. Wood treatment and log storage/sorting yards are covered in other sections of this chapter. Included in this group are planing mills, millworks, and businesses that make wooden containers and prefab building components, mobile homes, and glued-wood products, including: laminated beams, office and home furniture, partitions, and cabinets. All businesses employ cutting equipment whose by-products are chips and sawdust. Finishing is conducted in many operations.

Potential Pollutant Generating Sources: Businesses may have operations that use paints, solvents, wax emulsions, melamine formaldehyde and other thermosetting resins, and produce waste paints and paint thinners, turpentine, shellac, varnishes and other waste liquids. Outside storage, trucking, and handling of these materials can also be pollutant sources.

Potential pollutants reported in EPA's draft multi-sector permit/fact sheet (U.S. EPA, 1995) include the following (all are grab/composite mean values, in mg/L, except for oil and grease and pH): BOD at 39.6/45.4, COD at 297.6/242.5, NO3 + NO2-N at 0.95/0.75, total Kjeldahl nitrogen at 2.57/2.32, total P at 23.91/6.29; TSS at 1108/575, arsenic at .025/.028, copper at .047/.041, total phenols at .02/.007, oil and grease at 15.2, and pH at 3.6. These data may help in characterizing the potential stormwater pollutants at the facility.

Wood Treatment
SIC: 2491

Description: This group includes both anti-staining and wood preserving. The wood stock must be brought to the proper moisture content prior to treatment, which is achieved by either air-drying or kiln drying. Some wood trimming may occur. After treatment, the lumber is typically stored outside. Forklifts are used to move both the raw and finished product. Wood treatment consists of a pressure process using the chemicals described below. Anti-staining treatment is conducted using dip tanks or by spraying. Wood preservatives include creosote, creosote/coal tar, pentachlorophenol, copper naphthenate or inorganic arsenicals such as chromated copper arsenate dissolved in water. The use of pentachlorophenol is declining in the Puget Sound region.

Potential Pollutant Generating Sources: Potential pollutant generating sources/activities include: the retort area, handling of the treated wood, outside storage of treated materials/products, equipment/vehicle storage and maintenance, and the unloading, handling, and use of the preservative chemicals. Based on EPA's multi-sector permit/fact sheet (U.S. EPA, 1995) the following stormwater contaminants have been reported: COD, TSS, BOD, and the specific pesticide(s) used for the wood preservation.

Other Manufacturing Businesses
SIC: 2200, 2300, 2873/74, 3100, 3200, 3250-69, 3280, 3290

Description: Includes manufacturing of textiles and apparel, agricultural fertilizers, leather products, clay products such as bricks and pottery, bathroom fixtures, and nonmetallic mineral products.

Potential Pollutant Generating Sources: Pollutant generating sources at facilities in these categories include: fueling, loading and unloading, material storage and handling (especially fertilizers), and vehicle and equipment cleaning and maintenance. Potential pollutants include TSS, BOD, COD, oil and grease, heavy metals, and fertilizer components including nitrates, nitrites, ammonia nitrogen, Kjeldahl nitrogen, and phosphorous compounds.

Transportation and Communication

Airfields and Aircraft Maintenance
SIC: 4513, 4515

Description: Industrial activities include vehicle and equipment fueling, maintenance and cleaning, and aircraft/runway deicing.

Potential Pollutant Generating Sources: Fueling is accomplished by tank trucks at the aircraft and is a source of spills. Dripping of fuel and engine fluids from the aircraft and at vehicle/equipment maintenance/ cleaning areas, and application of deicing materials to the aircraft and the runways are potential sources of stormwater contamination. Aircraft maintenance and cleaning produces a wide variety of waste products, similar to those found with any vehicle or equipment maintenance, including: used oil and cleaning solvents, paints, oil filters, soiled rags, and soapy wastewater. Deicing materials used on aircraft and(or) runways include ethylene and propylene glycol and urea. Other chemicals currently considered for ice control are sodium and potassium acetates, isopropyl alcohol, and sodium fluoride. Pollutant constituents include oil and grease, TSS, BOD, COD, TKN, pH, and specific deicing components, such as glycol and urea.

Fleet Vehicle Yards
SIC: 4100, 4210, 4230, 7381/2, 7510

Description: Includes all businesses that own, operate and maintain or repair large vehicle fleets, including cars, buses, trucks and taxis, as well as, the renting or leasing of cars, trucks, and trailers.

Potential Pollutant Generating Sources:

- Spills/leaks of fuels, used oils, oil filters, antifreeze, solvents, brake fluid, and batteries, sulfuric acid, battery acid sludge, and leaching from empty contaminated containers and soiled rags.
- Leaking underground storage tanks that can cause groundwater contamination and is a safety hazard.
- Dirt, oils, and greases from outside steam cleaning and vehicle washing.
- Dripping of liquids from parked vehicles.
- Solid and liquid wastes (noted above) that are not properly stored while awaiting disposal or recycling.
- Loading and unloading area.

Railroads
SIC: 4011/13

Description: Railroad activities are spread over a large geographic area: along railroad lines, in switching yards, and in maintenance yards. Railroad activity occurs on both property owned or leased by the railroad and at the loading or unloading facilities of its customers. Employing BMPs at commercial or public loading and unloading areas is the responsibility of the particular property owner.

Potential Pollutant Generating Sources: The following are potential sources of pollutants: dripping of vehicle fluids onto the road bed, leaching of wood preservatives from the railroad ties, human waste disposal, litter, locomotive sanding areas, locomotive/railcar/equipment cleaning areas, fueling areas, outside material storage areas, the erosion and loss of soil particles from the bed, and herbicides used for vegetation management.

Maintenance activities include maintenance shops for vehicles and equipment, track maintenance, and ditch cleaning. In addition to the railroad stock, the maintenance shops service highway vehicles and other types of equipment. Waste materials can include waste oil, solvents, degreasers, antifreeze, radiator flush, acid solutions, brake fluids, soiled rags, oil filters, sulfuric acid and battery sludge, and machine chips with residual machining oil and any toxic fluids or solids lost during transit. The following are potential pollutants at rail yards: oil and grease, TSS, BOD, organics, pesticides, and heavy metals.

Warehouses and Mini-Warehouses SIC: 4220

Description: Businesses that store goods in buildings and other structures.

Potential Pollutant Generating Sources: The following are potential pollutant sources from warehousing operations: loading and unloading areas, outside storage of materials and equipment, fueling and maintenance areas. Potential pollutants include oil and grease and TSS.

Other Transportation and Communication SIC: 4700-4900

Description: This group includes travel agencies, communication services such as TV and radio stations, cable companies, and electric and gas services. It does not include railroads, airplane transport services, airlines, pipeline companies, and airfields.

Potential Pollutant Generating Sources: Gas and electric services are likely to own vehicles that are washed, fueled, and maintained on site. Communication service companies can generate used oils and dangerous wastes. The following are the potential pollutants: oil and grease, TSS, BOD, and heavy metals.

Retail and Wholesale Businesses

Gas Stations SIC: 5540

Refer to BMPs for Fueling at Dedicated Stations in Section 8.2 to select applicable BMPs.

Recyclers and Scrap Yards SIC: 5093, 5015

Refer to BMPs for Recyclers and Scrap Yards.

Commercial Composting SIC 2875

Description: This typically applies to businesses that have numerous compost piles that require large open areas to break down the wastes.

Potential Pollutant Generating Sources: Composting can contribute nutrients, organics, coliform bacteria, low pH, color, and suspended solids to stormwater runoff.

Restaurants/Fast Food
SIC: 5800

Description: Businesses that provide food service to the general public, including drive through facilities.

Potential Pollutant Generating Sources: Potential pollutant sources include high-use customer parking lots and garbage dumpsters. The cleaning of roofs and other outside areas of restaurant and cooking vent filters in the parking lot can cause cooking grease to be discharged to the storm drains. The discharge of wash water or grease to storm drains or surface water is not allowed.

Retail/General Merchandise
SIC: 5300, 5600, 5700, 5900, and 5990

Description: This group includes general merchandising stores, such as department stores, shopping malls, variety stores, 24-hour convenience stores, and general retail stores that focus on a few product types, such as clothing and shoes. It also includes furniture and appliance stores.

Potential Pollutant Generating Sources: Of particular concern are the high-use parking lots of shopping malls and 24-hour convenience stores. Furniture and appliance stores may provide repair services in which dangerous wastes may be produced.

Retail/Wholesale Vehicle and Equipment Dealers
SIC: 5010, 5080, and 5500, 751 excluding fueling stations (5540)

Description: This group includes all retail and wholesale businesses that sell, rent, or lease cars, trucks, boats, trailers, mobile homes, motorcycles, and recreational vehicles. It includes both new and used vehicle dealers. It also includes sellers of heavy equipment for construction, farming, and industry. With the exception of motorcycle dealers, these businesses have large parking lots. Most retail dealers that sell new vehicles and large equipment also provide repair and maintenance services.

Potential Pollutant Generating Sources: Oil and other materials that have dripped from parked vehicles can contaminate stormwater at high-use parking areas. Vehicles are washed regularly, generating vehicle grime and detergent pollutants. The storm or wash water runoff will contain oils and various organics, metals, and phosphorus. Repair and maintenance services generate a variety of waste liquids and solids, including used oils and engine fluids, solvents, waste paint, soiled rags, and dirty used engine parts. Many of these materials are dangerous wastes.

Retail/Wholesale Nurseries and Building Materials
SIC: 5030, 5198, 5210, 5230, and 5260

Description: These businesses are placed in a separate group because they are likely to store much of their merchandise outside of the main building. They include nurseries, and businesses that sell building and construction materials and equipment, paint (5198, 5230), and hardware.

Potential Pollutant Generating Sources: Some businesses may have small fueling capabilities for forklifts and may also maintain and repair their vehicles and equipment. Some businesses may have unpaved areas, with the potential to contaminate stormwater by leaching of nutrients, pesticides, and herbicides. Businesses in this group surveyed in the Puget Sound area for dangerous wastes were found to produce waste solvents, paints, and used oil. Storm runoff from exposed storage areas can contain suspended solids, and oil and grease from vehicles, forklifts and high-use customer parking lots, and other pollutants. Runoff from nurseries may contain nutrients, pesticides and(or) herbicides.

Retail/Wholesale Chemicals and Petroleum
SIC: 5160, 5170

Description: These businesses sell plastic materials, chemicals and related products. This group also includes the bulk storage and selling of petroleum products, such as diesel oil, automotive fuels, etc.

Potential Pollutant Generating Sources: The general areas of concern are the spillage of chemicals or petroleum during loading and unloading, and the washing and maintenance of tanker trucks and other vehicles. Also, the fire code requires that vegetation be controlled within a tank farm to avoid a fire hazard. Herbicides are typically used. The concentration of oil in untreated stormwater is known to exceed the water quality effluent guideline for oil and grease. Runoff is also likely to contain significant concentrations of benzene, phenol, chloroform, lead, and zinc.

Retail/Wholesale Foods and Beverages
SIC 5140, 5180, 541, 542, 543

Description: These businesses provide retail food stores, including general groceries, with fish and seafood, meats and meat products, dairy products, poultry, soft drinks, and alcoholic beverages.

Potential Pollutant Generating Sources: Vehicles may be fueled, washed and maintained at the business. Spillage of food and beverages may occur. Waste food and broken contaminated glass may be temporarily stored in containers located outside. High-use customer parking lots may be sources of oil and other contaminants.

Other Retail/Wholesale Businesses
SIC: 5010 (not 5012), 5040, 5060, 5070, 5090, 515

Description: Businesses in this group include sellers of vehicle parts, tires, furniture and home furnishings, photographic and office equipment, electrical goods, sporting goods and toys, paper products, drugs, and apparel.

Potential Pollutant Generating Sources: Pollutant sources include high-use parking lots, and delivery vehicles that may be fueled, washed, and maintained on premises.

Service Businesses

Animal Care Services
SIC: 0740, 0750

Description: This group includes racetracks, kennels, fenced pens, veterinarians and businesses that provide boarding services for animals, including horses, dogs, and cats.

Potential Pollutant Generating Sources: The primary sources of pollution include animal manure, wash waters, waste products from animal treatment, runoff from pastures where larger livestock are allowed to roam, and vehicle maintenance and repair shops. Pastures may border streams and direct access to the stream may occur. Both surface water and groundwater may be contaminated. Potential stormwater contaminants include fecal coliform, oil and grease, suspended solids, BOD, and nutrients.

Commercial Car and Truck Washes SIC: 7542

Description: Facilities include automatic systems found at individual businesses or at gas stations and 24-hour convenience stores, as well as self-service. There are three main types: tunnels, rollovers, and hand-held wands. The tunnel wash, the largest, is housed in a long building through which the vehicle is pulled. At a rollover wash the vehicle remains stationary while the equipment passes over. Wands are used at self-serve car washes. Some car washing businesses also sell gasoline.

Potential Pollutant Generating Sources: Wash wastewater may contain detergents and waxes. Wastewater should be discharged to sanitary sewers. In self-service operations a drain is located inside each car bay. Although these businesses discharge the wastewater to the sanitary sewer, some wash water can find its way to the storm drain, particularly with the rollover and wand systems. Rollover systems often do not have air-drying. Consequently, as it leaves the enclosure the car sheds water to the pavement. With the self-service system, wash water with detergents can spray outside the building and drain to storm sewer. Users of self-serve operations may also clean engines and change oil, dumping the used oil into the storm drain. Potential pollutants include oil and grease, detergents, soaps, BOD, and TSS.

Equipment Repair SIC: 7353, 7600

Description: This group includes several businesses that specialize in repairing different equipment including: communications equipment, radio, TV, household appliances, and refrigeration systems. Also included are businesses that rent or lease heavy construction equipment, because miscellaneous repair and maintenance may occur on site.

Potential Pollutant Generating Sources: Potential pollutant sources include storage and handling of fuels, waste oils and solvents, and loading/unloading areas. Potential pollutants include oil and grease, low/high pH, and suspended solids.

Laundries and Other Cleaning Services SIC: 7211 through 7217

Description: This category includes all types of cleaning services, such as laundries, linen suppliers, diaper services, coin-operated laundries and dry cleaners, and carpet and upholstery services. Wet washing may involve the use of acids, bleaches, and(or) multiple organic solvents. Dry cleaners use an organic-based solvent, although small amounts of water and detergent are sometimes used. Solvents may be recovered and filtered for further use. Carpets and upholstery may be cleaned with dry materials, hot water extraction process, or in-plant processes using solvents followed by a detergent wash.

Potential Pollutant Generating Sources: Wash liquids are discharged to sanitary sewers. Stormwater pollutant sources include: loading and unloading of liquid materials, particularly at large commercial operations, disposal of spent solvents and solvent cans, high-use customer parking lots, and outside storage and handling of solvents and waste materials. Potential stormwater contaminants include oil and grease, chlorinated and other solvents, soaps and detergents, low/high pH, and suspended solids.

Marinas and Boat Clubs
SIC: 7999

Description: Marinas and yacht clubs provide moorage for recreational boats. Marinas may also provide fueling and maintenance services. Other activities include cleaning and painting of boat surfaces, minor boat repair, and pumping of bilges and sanitary holding tanks. Not all marinas have a system to receive pumped bilge water.

Potential Pollutant Generating Sources: Both solid and liquid wastes are produced as well as stormwater runoff from high-use customer parking lots. Waste materials include sewage and bilge water. Maintenance by the tenants will produce used oils, oil filters, solvents, waste paints and varnishes, used batteries, and empty contaminated containers and soiled rags. Potential stormwater contaminants include oil and grease, suspended solids, heavy metals, and low/high pH.

Golf and Country Clubs
SIC: 7992, 7997

Description: Public and private golf courses and parks are included.

Potential Pollutant Generating Sources: Maintenance of grassed areas and landscaped vegetation has historically required the use of fertilizers and pesticides. Golf courses contain small lakes that are sometimes treated with algaecides and/or mosquito larvicides. The fertilizer and pesticide application process can lead to inadvertent contamination of nearby surface waters by overuse, misapplication, or the occurrence of storms shortly after application. Heavy watering of surface greens in golf courses may cause pesticides or fertilizers to migrate to surface and shallow ground water resources. The use of pesticides and fertilizers generates waste containers. Equipment must be cleaned and maintained.

Miscellaneous Services
SIC: 4959, 7260, 7312, 7332, 7333, 7340, 7395, 7641, 7990, 8411

Description: This group includes photographic studios, commercial photography, funeral services, amusement parks, furniture and upholstery repair, pest control services, and other professional offices.

Potential Pollutant Generating Sources: Pollutants from these activities may include: pesticides, waste solvents, heavy metals, pH, suspended solids, soaps and detergents, and oil and grease.

Professional Services
SIC: 6000, 7000 and 8000, 806, 807 not listed elsewhere

Description: The remaining service businesses include theaters, hotels/motels, finance, banking, hospitals, medical/dental laboratories, medical services, nursing homes, schools/universities, and legal, financial, and engineering services.

Stormwater from parking lots will contain undesirable concentrations of oil and grease, suspended particulates, and metals, such as lead, cadmium, and zinc. Dangerous wastes might be generated at hospitals, nursing homes, and other medical services.

Potential Pollutant Generating Sources: Leaks and spills of materials from the following businesses can be sources of stormwater pollutants:

- Building maintenance produces wash and rinse solutions, oils, and solvents.

- Pest control produces rinse water with residual pesticides from washing application equipment and empty containers.
- Outdoor advertising produces photographic chemicals, inks, waste paints, organic paint sludges containing metals.
- Funeral services produce formalin, formaldehyde, and ammonia.
- Upholstery and furniture repair businesses produce oil, stripping compounds, wood preservatives and solvents.

Other Potential Pollutant Generating Sources: The primary concern is runoff from high use parking areas, maintenance shops, and storage and handling of dangerous wastes.

Vehicle Maintenance and Repair
SIC: 4000, 7530, 7600

Description: This category includes businesses that paint, repair and maintain automobiles, motorcycles, trucks, and buses; and battery, radiator, muffler, lube, tune-up and tire shops, excluding those businesses listed elsewhere in this manual.

Potential Pollutant Generating Sources: Pollutant sources include: storage and handling of vehicles, solvents, cleaning chemicals, waste materials, vehicle liquids, batteries, and washing and steam cleaning of vehicles, parts, and equipment. Potential pollutants include: waste oil, solvents, degreasers, antifreeze, radiator flush, acid solutions with chromium, zinc, copper, lead and cadmium, brake fluid, soiled rags, oil filters, sulfuric acid and battery sludge, and machine chips in residual machining oil.

Multi-Family Residences SIC: NA

Description: Multifamily residential buildings such as apartments and condominiums. The activities of concern are vehicle parking, vehicle washing and oil changing, minor repairs, and temporary storage of garbage.

Potential Pollutant Generating Sources: Stormwater contamination can occur at vehicle parking lots and from washing of vehicles. Runoff from parking lots may contain undesirable concentrations of oil and grease, suspended particulates, and metals such as lead, cadmium, and zinc.

Construction Businesses SIC: 1500, 1600, 1700

Description: This category includes builders of homes, commercial and industrial buildings, and heavy equipment, as well as plumbing, painting and paper hanging, carpentry, electrical, roofing and sheet metal, wrecking and demolition, stonework, drywall, and masonry contractors. It does not include construction sites.

Potential Pollutant Generating Sources: Potential pollutant sources include leaks/spills of used oils, solvents, paints, batteries, acids, strong acid/alkaline wastes, paint/varnish removers, tars, soaps, coatings, asbestos, lubricants, anti-freeze compounds, litter; and fuels at the headquarters, operation, staging, and maintenance/repair locations of the businesses.

Demolition contractors may store reclaimed material before resale. Roofing contractors generate residual tars and sealing compounds, spent solvents, kerosene, and soap cleaners, as well as non-hazardous waste roofing materials. Sheet metal contractors produce small quantities of acids and solvent cleaners, such as kerosene, metal shavings, adhesive residues and enamel coatings, and asbestos residues that have been removed from buildings. Asphalt paving contractors are likely to store application equipment, such as dump trucks, pavers, tack coat tankers, and pavement rollers at their businesses. Stormwater passing through this equipment may be contaminated by the petroleum residuals. Potential pollutants include oil and grease, suspended solids, BOD, heavy metals, pH, COD, organic compounds, etc.

Public Agency Activities

Local, state, and federal governments conduct many of the pollutant generating activities conducted at business facilities. Local governments include cities and counties, and also single-purpose entities such as fire, sewer, and water districts.

Public Facilities and Streets

Description: Included in this group are public buildings. Also included are maintenance (deicing), and repair of streets and roads.

Potential Pollutant Generating Sources: Wastes generated include deicing and anti-icing compounds, solvents, paint, acid and alkaline wastes, paint and varnish removers, and debris. Large amounts of scrap materials are also produced throughout the course of construction and street repair. Potential pollutants include suspended solids, oil and grease, and low/high pH.

Maintenance of Open Public Space Areas

Description: The maintenance of large open spaces that are covered by expanses of grass and landscaped vegetation. Examples are zoos and public cemeteries. Golf courses and parks are also covered earlier in this chapter.

Potential Pollutant Generating Sources: Maintenance of grassed areas and landscaped vegetation has historically required the use of fertilizers and pesticides. Golf courses contain small lakes that are sometimes treated with algaecides and(or) mosquito larvicides. The application of pesticides can lead to inadvertent contamination of nearby surface waters by overuse, misapplication, or the occurrence of storms shortly after application. Heavy watering of surface greens in golf courses may cause pesticides or fertilizers to migrate to surface and shallow groundwater resources. The application of pesticides and fertilizers generates waste containers. Equipment must be cleaned and maintained. Maintenance shops where the equipment is maintained must comply with the BMPs specified under BMP Maintenance and Repair of Vehicles and Equipment.

Maintenance of Public Stormwater Pollutant Control Facilities

Description: Facilities include roadside catch basins on arterials and within residential areas, conveyance pipes, detention facilities, such as ponds and vaults, oil and water separators, biofilters, settling basins, infiltration systems, and all other types of stormwater treatment systems.

Potential Pollutant Generating Sources: Research has shown that roadside catch basins can remove from 5 to 15 percent of the pollutants present in stormwater. However, to be effective they must be cleaned. Research has indicated that once catch basins are about 60 percent full of sediment, they cease removing sediments. Generally in urban areas, catch basins become 60 percent full within 6 to 12 months.

Water and solids produced during the cleaning of stormwater treatment systems, including oil and water separators, can adversely affect both surface and groundwater quality if disposed of improperly. Ecology has documented water quality violations and fish kills due to improper disposal of decant water (water that is removed) and catch basin sediments from maintenance activities. Disposal of decant water and solids shall be conducted in accordance with local, state, and federal requirements.

Historically, decant water from trucks has been placed back in the storm drain. Solids have been disposed of in permitted landfills and in unpermitted vacant land including wetlands. Research has shown that these residuals contain pollutants at concentrations that exceed water quality criteria. For example, limited sampling by King County and the Washington Department of Transportation of sediments removed from catch basins in residential and commercial areas has found the petroleum hydrocarbons to frequently exceed 200 mg/gram. Above this concentration, regulations require disposal at a lined landfill.

Water and Sewer Districts and Departments

Description: The maintenance of water and sewer systems can produce residual materials that, if not properly handled, can cause short-term environmental impacts in adjacent surface and(or) groundwaters. With the exception of a few simple processes, both water and sewage treatment produce residual sludge that must be disposed of properly. However, this activity is controlled by other Ecology regulatory programs and is not discussed in this Manual. Larger water and sewer districts or departments may service their own vehicles.

Port Districts

Description: The port districts considered here include the following business activities: recreational boat marinas and launch ramps; airfields; container trans-shipment; bulk material import/export, including farm products, lumber, logs, alumina, and cement; and break-bulk (piece) material, such as machinery, equipment, and scrap metals. Port districts frequently have tenants whose activities are not marine-dependent.

Potential Pollutant Generating Sources: Maintenance operations of concern include: the cleaning of sewers, water lines, and water reservoirs; general activities around treatment plants, disposal of sludge; and the temporary shutdown of pump stations for either normal maintenance or emergencies. During the maintenance of water transmission lines and reservoirs, water district/departments must dispose of wastewater, both when the line or reservoir is initially emptied, as well as when it is cleaned and then sanitized. Sanitation requires chlorine concentrations of 25 to 100 ppm, considerably above the normal concentration used to chlorinate drinking water. These waters are discharged to sanitary sewers where available.

However, transmission lines from remote water supply sources often pass through both rural and urban-fringe areas where sanitary sewers are not available. In these areas, chlorinated water may have to be discharged to a nearby stream or storm drain, particularly since the emptying of a pipe section occurs at low points that frequently exist at stream crossings. Although prior to disposal the water is dechlorinated using sodium thiosulfate or a comparable chemical, malfunctioning of the dechlorination system can kill fish and other aquatic life. The drainage from reservoirs located in unsewered areas is conveyed to storm drains. The cleaning of sewer lines and manholes generates sediments. These sediments contain both inorganic and organic materials are odorous and contaminated with microorganisms and heavy metals. Activities around sewage treatment plants can be a source of non-point pollution. Besides the normal runoff of stormwater from paved surfaces, grit removed from the headworks of the plant is stored temporarily in dumpsters that may be exposed to the elements. Maintenance and repair shops may produce waste paints, used oil, cleaning solvents, and soiled rags.

Potential Pollutant Generating Sources: Marine terminals require extensive use of mobile equipment that may drip liquids. Waste materials associated with containers/vehicle/equipment washing/steam cleaning, maintenance and repair may be generated at a marine terminal. Debris can accumulate in loading/unloading or open storage areas, providing a source of stormwater contamination. Wooden debris from the crating of piece cargo crushed by passing mobile loading equipment leaches soluble pollutants when in contact with pooled stormwater. Log sorting yards produce large quantities of bark that can be a source of suspended solids and leached pollutants. Potential pollutants include oil and grease, TSS, heavy metals, and organics.

Appendix 8B – Best Management Practices for Managing Street Waste

Introduction

This appendix is a summary, taken from Ecology's Publication WQ 99-09. The guidance document addresses waste generated from stormwater maintenance activities such as street sweeping and the cleaning of catch basins, and to a limited extent, other stormwater conveyance and treatment facilities. Limited information is available on the characteristics of wastes from detention/retention ponds, bioswales, and similar stormwater treatment facilities. The recommendations provided here may be generally applicable to these facilities, with extra diligence given to waste characterization.

These recommendations do not constitute rules or regulations, but are suggestions for street waste handling, reuse, and disposal using current regulations and the present state of knowledge of street waste constituents. The recommendations are intended to address the liquid and solid wastes collected during routine maintenance of stormwater catch basins, detention/retention ponds and ditches and similar stormwater treatment and conveyance structures, and street and parking lot sweeping. In addition to these recommendations, end users and other authorities may have their own requirements for street waste reuse and handling.

"Street Wastes" include liquid and solid wastes collected during maintenance of stormwater catch basins, detention/retention ponds and ditches and similar stormwater treatment and conveyance structures, and solid wastes collected during street and parking lot sweeping.

"Street Wastes" as defined here do not include solids and liquids from street washing using detergents, cleaning of electrical vaults, vehicle wash sediment traps, restaurant grease traps, industrial process waste, sanitary sewage, mixed process, or combined sewage/stormwater wastes. Wastes from oil/water separators at sites that load fuel are not included as street waste. Street waste also does not include flood debris, land slide debris, and chip seal gravel.

<u>Street waste does not ordinarily classify as dangerous waste.</u> The owner of the stormwater facility and(or) collector of street waste is considered the waste generator and is responsible for determining whether or not the waste designates as dangerous waste. Sampling to date has shown that material from routine maintenance of streets and stormwater facilities does not classify as dangerous waste. However, it is possible that street waste from spill sites could classify as dangerous waste. Street waste from areas with exceptionally high average daily traffic counts may contain contaminants, such as heavy metals, total petroleum hydrocarbons (TPH),

and carcinogenic polycyclic aromatic hydrocarbons (c-PAH), at levels that limit reuse options.

Street waste is solid waste. While street waste from normal street and highway maintenance is not dangerous waste, it is solid waste, as defined under The Solid Waste Management Act (Chapter 70.95 RCW) and under Minimum Functional Standards for Solid Waste Handling (Chapter 173-304 WAC – these are under revision and will be renamed 173-350). Under the Solid Waste Management Act, local health departments have primary jurisdiction over solid waste management. Street waste solids may contain contaminants at levels too high to allow unrestricted reuse. There are currently no specific references in the Minimum Functional Standards to facilities managing street waste solids. These facilities will typically fit under the section dealing with Piles Used for Storage and Treatment. There are no specific references for reuse and disposal options for street wastes in the Minimum Functional Standards, although the Minimum Functional Standards do not apply to clean soils. In the proposed rule, clean soils are defined as 'soils that do not contain contaminants at concentrations which could degrade the quality of air, waters of the state, soils, or sediments; or pose a thereat to the health of humans or other living organisms' (WAC 173-350-100). Whether or not a soil is a clean soil depends primarily upon the level of contaminants and, to a lesser degree, on the background level of contaminants at a particular location and the exposure potential to humans or other living organisms. Therefore, both the soil and potential land application sites must be evaluated to determine if a soil is a clean soil. Local health departments should be contacted to determine if a street waste meets the definition of "clean soil" when it will be reused as a soil.

There is no simple regulatory mechanism available to classify street waste solids as "clean" for uncontrolled reuse or disposal. Local health districts have historically used the Model Toxics Control Act Cleanup Regulation (MTCA) Method A residential soil cleanup levels to approximate "clean" and to make decisions on land application proposals. These regulations were amended in February 2001. Although, these regulations were not intended to be used for making decisions on land application proposals, they may provide a useful framework for such a decision, when used in conjunction with other health and environmental considerations. The local health department should be contacted to determine local requirements for making this determination.

Recommendations for Re-Use and Disposal of Street Waste Solids

General Handling Recommendations

Permitting of street waste treatment and storage facilities as solid waste handling facilities by the local health department is required. Under the

Solid Waste Management Act, local health departments have primary jurisdiction over solid waste management. Street waste handling facilities are subject to the requirements of the “Minimal Functional Standards for Solid Waste Handling.” The specific requirements will depend upon the manner in which the waste is managed. Most facilities will probably be permitted under the section dealing with “Piles Used for Storage and Treatment” (Section 320 of the proposed revisions).

For most facilities, permit requirements include a plan of operation, sampling, record keeping and reporting, inspections, and compliance with other state and local requirements. The plan of operation should include a procedure for characterization of the waste and appropriate reuse and disposal options, consistent with the recommendations in this document and applicable federal, state and local requirements.

A street waste site evaluation (see sample at end of this report) is suggested for all street waste as a method to identify spill sites or locations that are more polluted than normal. The disposal and reuse options listed below are based on characteristics of routine street waste and are not appropriate for more polluted wastes. The collector of street waste should evaluate it both for its potential to be classified as dangerous waste and to not meet end users requirements.

Street waste that is suspected to be dangerous waste should not be collected with other street waste. Material in catch basins with obvious contamination (unusual color, staining, corrosion, unusual odors, fumes, and oily sheen) should be left in place or segregated until tested. Testing should be based on probable contaminants. Street waste that is suspected to be dangerous waste should be collected and handled by someone experienced in handling dangerous waste. Potential dangerous waste must be collected because of emergency conditions, or if the waste becomes suspect after it is collected, it should be handled and stored separately until a determination as to proper disposal is made. Street waste treatment and storage facilities should have separate "hot load" storage areas for such waste. Dangerous waste includes street waste known and suspected to be dangerous waste. This waste must be handled following the Dangerous Waste Regulations (Chapter 173-303 WAC) unless testing determines it is not dangerous waste.

Spills should be handled by trained specialists. Public works maintenance crews and private operators conducting street sweeping or cleaning catch basins should have written policies and procedures for dealing with spills or suspected spill materials. Emergency Spill Response telephone numbers should be immediately available as part of these operating policies and procedures.

The end recipient of street waste must be informed of its source and may have additional requirements for its use or testing that are not listed here.

This document is based primarily on average street waste's chemical constituents and their potential affect on human health and the environment. There are physical constituents (for example, broken glass or hypodermic needles) or characteristics (for example, fine grain size) that could also limit reuse options. Additional treatment such as drying, sorting, or screening may also be required, depending on the needs and requirements of the end user.

Street waste treatment and storage facilities owned or operated by governmental agencies should be made available to private waste collectors and other governmental agencies on a cost recovery basis. Proper street waste collection and disposal reduces the amount of waste released to the environment. The operators of street waste facilities should restrict the use of their facilities to certified and(or) licensed waste collectors who meet their training and liability requirements.

The use of street waste solids under this guidance should not lead to designation as a hazardous waste site, requiring cleanup under MTCA. Exceeding MTCA Method A unrestricted land use cleanup levels in street waste and products made from street waste, does not automatically make the site where street waste is reused a cleanup site. A site is reportable only if "a release poses a threat to human health or the environment" (Model Toxic Control Act). The reuse options proposed below are designed to meet the condition of not posing a threat to human health or the environment. Please note that some of the suggested maximum values in Table 8B-1 are based on soil cleanup criteria for unrestricted land uses. Values that exceed these suggested thresholds are not necessarily precluded from reuse. The local health jurisdiction should be consulted to determine appropriate reuse options.

Testing of street waste solids will generally be required as part of a plan of operation that includes procedures for characterization of the waste. Testing frequency, numbers of samples, parameters to be analyzed, and contaminant limit criteria should all be provided as part of an approved plan of operation. Tables 8B-1 and 8B-2, at the end of this section, provide some recommended parameters and sampling frequencies for piles of street waste solids from routine street maintenance. These are provided as guidance only, and are intended to assist the utility and the local health department in determining appropriate requirements. Sampling requirements may be modified, over time, based on accumulated data. When the material is from a street waste facility or an area that has never been characterized by testing, the test should be conducted on a representative sample before co-mingling with other material. Testing in these instances would be to demonstrate that the waste does not designate as dangerous waste and to characterize the waste for reuse. At a minimum, the parameters in Table 8B-1 are recommended for these cases. Note that it will generally not be necessary to conduct TCLP analyses when the observed values do not exceed the recommended values in Table 8B-1.

For further information on testing methods and sampling plans, refer to:

- SW 846 (US EPA, Office of Solid Waste, Test Methods for Evaluating Solid Wastes, 3rd Ed.) and
- Standard Methods for the Examination of Water and Wastewater (American Public Health Association, et al., 18th Edition 1992)

<u>For street waste not exceeding the suggested maximum values in Table 8B-1 the following street waste solids reuse and disposal options are recommended:</u>

- Street sweepings that consist primarily of leaves, pine needles and branches, and grass cuttings from mowing grassy swales can be composted. Litter and other foreign material must be removed prior to composting or the composting facility must provide for such removal as part of the process. The screened trash is solid waste and must be disposed of at an appropriate solid waste handling facility.
- Coarse sand screened from street sweeping after recent road sanding, may be reused for street sanding, providing there is no obvious contamination from spills. The screened trash is solid waste and must be disposed of at an appropriate solid waste handling facility.
- Roadside ditch cleanings, not contaminated by a spill or other release and not associated with a stormwater treatment system such as a bioswale, may be screened to remove litter and separated into soil and vegetative matter (leaves, grass, needles, branches, etc.). The soils from these activities are not generally regulated as solid waste. Ditching material that may be contaminated must be stored, tested and handled in the same manner as other street waste solids. It is the generator's responsibility to visually inspect and otherwise determine whether the materials may be contaminated.
- Construction street wastes, the solids collected from sweeping or in stormwater treatment systems at active construction sites, may be placed back onto the site that generated it, or managed by one on the methods listed below, provided that it has not been contaminated as a result of a spill. For concrete handling at construction site, refer to BMP C151 in Volume II, Construction Stormwater Pollution Prevention in the *Stormwater Management Manual for Western Washington*.
- Screened street waste soils may be used as feedstock materials for topsoil operations. This option should be reserved for street waste soils with very low levels of contaminants. Diluting street waste soils with clean soils or composted material must not be used as a substitute for treatment or disposal. There may be physical contaminants (for

example, glass, metal, nails, etc.) in street waste that cannot be entirely screened from the waste. Where present, these contaminants in street waste could preclude its use as feedstock material for topsoil operations.

- Fill in parks, play fields, golf courses, and other recreational settings, where direct exposure by the public is limited or prevented. One way to accomplish this is to cover the fill with sod, grass, or other capping material to reduce the risk of soil being ingested. The level of contaminants in the street waste must be evaluated to ensure that the soils meet the definition of clean soils when used in this manner.
- Fill in commercial and industrial areas, including soil or top dressing for use at industrial sites, roadway medians, airport infields and similar sites, where there is limited direct human contact with the soil, and the soils will be stabilized with vegetation or other means. The level of contaminants in the street waste must be evaluated to ensure that the soils meet the definition of clean soils when used in this manner.
- Top dressing on roadway slopes, road or parking lot construction material and road subgrade, parking lot subgrade, or other road fill. The level of contaminants in the street waste must be evaluated to ensure that the soils meet the definition of clean soils when used in this manner.
- Daily cover or fill in a permitted municipal solid waste landfill, provided the street waste solids have been dewatered. Street waste solids may be acceptable as final cover during a landfill closure. The local health department and landfill operator should be consulted to determine conditions of acceptance.
- Treatment at a permitted contaminated soil treatment facility.
- Recycling through incorporation into a manufactured product, such as Portland cement, prefab concrete, or asphalt. The facility operator should be consulted to determine conditions of acceptance.
- Other end-use as approved by the local health department
- Disposal at an appropriate solid waste handling facility.

<u>For street waste that exceed the suggested maximum values in Table 8B-1 the following street waste solids reuse and disposal options are recommended:</u>

- Treatment at a permitted contaminated soil treatment facility.
- Recycling through incorporation into a manufactured product, such as Portland cement, prefab concrete, or asphalt. The facility operator should be consulted to determine conditions of acceptance.

- Other end-use as approved by the local health department. Some of the suggested maximum values in Table 8B-1 are based on soil cleanup criteria for unrestricted land uses. Values that exceed these suggested thresholds are not necessarily precluded from reuse. The local health jurisdiction should be consulted to determine appropriate reuse options.
- Disposal at an appropriate solid waste handling facility.

Table 8B-1
Recommended Parameters and Suggested Values
for Determining Reuse and Disposal Options

Parameter	Suggested Maximum Value
Arsenic, total	20.0 mg/kg [a]
Cadmium, total	2.0 mg/kg [b]
Chromium, total	42 mg/kg [c]
Lead, total	250 mg/kg [d]
Nickel	100 mg/kg [e]
Zinc	270 mg/kg [e]
Mercury (inorganic)	2.0 mg/kg [f]
PAHs (carcinogenic)	0.1 – 2.0 mg/kg [g]
TPH (heavy fuel oil)	200 - 460 mg/kg [h]
TPH (diesel)	200 – 460 mg/kg [h]
TPH (gasoline)	100 mg/kg [i]
Benzene	0.03 mg/kg [i]
Ethylbenzene	6 mg/kg [i]
Toluene	7 mg/kg [i]
Xylenes (total)	9 mg/kg [i]

[a] Arsenic: from MTCA Method A - Table 740-1: Soil cleanup levels for unrestricted land uses

[b] Cadmium: from MTCA Method A – Table 740-1: Soil cleanup levels for unrestricted land uses s.

[c] Chromium; from MTCA Method A - Table 740-1: Soil cleanup levels for unrestricted land uses

[d] Lead; from MTCA Method A – Table 740-1: Soil cleanup levels for unrestricted land uses

[e] Nickel and Zinc; from MTCA Table 749-2: Protection of Terrestrial Plants and Animals

[f] Mercury; from MTCA Method A – Table 740-1: Soil cleanup levels for unrestricted land uses

[g] PAH-Carcinogenic; from MTCA Method A – Table 740-1: Soil cleanup levels for unrestricted land uses and Table 745-1, industrial properties, based on cancer risk via direct contact with contaminated soil (ingestion of soil) in residential land use situations and commercial/industrial land uses. Note: The local health department may permit higher levels as part of a Plan of Operation, where they determine that the proposed end use poses little risk of direct human contact or ingestion of soil.

[h] TPH: from MTCA Tables 749-2 & 749-3: Protection of Terrestrial Plants and Animals. Values up to 460 mg/kg may be acceptable where the soils are capped or covered to reduce or prevent exposure to terrestrial plants and animals. Where the laboratory results report no ‘fingerprint’ or chromatographic match to known petroleum hydrocarbons, the soils will not be considered to be petroleum contaminated soils.

[i] BETX; from MTCA Method A - Table 740-1: Soil cleanup levels for unrestricted land uses.

Table 8B-2
Recommended Sampling Frequency for Street Waste Solids

Cubic Yards of Solids	Minimum Number of Samples
0 – 100	3
101 – 500	5
501 – 1000	7
1001 – 2000	10
>2000	10 + 1 for each additional 500 cubic yards

Modified from Ecology's Interim Compost Guidelines

This table is provided as guidance and is intended to assist the utility and the local health department in determining appropriate requirements. Sampling requirements may be modified, over time, based on accumulated data. When the material is from a street waste facility or an area that has never been characterized by testing, the test should be conducted on a representative sample before co-mingling with other material.

Recommendations for Disposal of Street Waste Liquids

General Handling Recommendations

- Street waste collection should emphasize solids in preference to liquids. Street waste solids are the principal objective in street waste collection and are substantially easier to store and treat than liquids.
- Street waste liquids require treatment and(or) must follow location limitations before their discharge. Street waste liquids usually contain high amounts of suspended and total solids, and adsorbed metals. Treatment requirements depend on the discharge location.
- Discharges to sanitary sewer and storm sewer systems must be approved by the entity responsible for operation and maintenance of the system. Ecology will not generally require waste discharge permits for discharge of stormwater decant to sanitary sewers or to stormwater treatment BMPs constructed and maintained in accordance with Ecology's Stormwater Management Manual for Western Washington.

The following disposal options are recommended, in order of preference, for catch basin decant liquid and for water removed from stormwater treatment facilities.

Under the Municipal General Permit, municipalities are required to use this guidance in determining appropriate means of dealing with street wastes from stormwater maintenance activities. Your regional Ecology water quality staff can help you with treatment standards and permit requirements for your particular situation.

Discharge of catch basin decant liquids to a municipal sanitary sewer connected to a Public Owned Treatment Works (POTW) is the preferred disposal option.

Discharge to a municipal sanitary sewer requires the approval of the local jurisdiction. Street waste liquids discharged to a POTW may be treated at a combined street waste liquid and solid facility (decant facility) or at separate liquids only facilities. These liquid only facilities may consist of modified type 2 catch basins (with a flow restrictor or oil/water separator) or water quality vaults, strategically located through the sanitary collection system. These should provide at least 4 – 6 hours detention for the expected volumes and should be constructed and operated to ensure that the decant discharge does not re-suspend sediments. Sewer authorities should require periodic sampling, and decant facility operators should test their waste effluent on a regular basis. It may be desirable to operate these decant facilities as 'batch treatment' devices, with valves that allow the operator to release settled water before decanting the next load. Such a system would also allow isolating a 'hot load' and retaining it until it can be tested. Quiescent settling, with retention times of 4 – 6 hours, will likely meet most local pretreatment requirements.

State and local regulations generally prohibit discharge of stormwater runoff into sanitary sewers, to avoid hydraulic overloads and treatment performance problems. The relatively small volume of stormwater discharged from cleaning catch basins and small stormwater treatment facilities is generally not sufficient to be a problem, provided the discharge point is properly selected and designed.

Stormwater removed from catch basins and stormwater treatment wetvaults may be discharged into a Basic Stormwater Treatment Facility.

Decant liquid collected from cleaning catch basins and stormwater treatment wetvaults may be discharged back into the storm sewer system under the following conditions:

- The preferred disposal option of discharge to sanitary sewer is not reasonably available, and
- The discharge is to a Basic Stormwater Treatment Facility (See Chapter 5), and

- The storm sewer system owner/operator has granted approval and has determined that the treatment facility will accommodate the increased loading.

Where the receiving treatment facility is a wetpool device, the volume of the wet pool should be significantly greater than the volume of decanted stormwater. The volume of decant discharged should not be greater than 5% of the volume of the wetpool and the discharge must be managed to prevent scouring and re-suspension of sediments in the wetpool. Direct discharge of decanted stormwater to biofiltration or infiltration facilities is discouraged. For these facilities, pretreatment is necessary to protect the facility.

Reasonably available will be determined by the stormwater utility and by the circumstances, including such factors as distance, time of travel, load restrictions, and capacity of the stormwater treatment facility. Some jurisdictions may choose not to allow discharge back to the storm sewer system.

<u>Discharge back into the storm sewer is an acceptable option, under certain conditions:</u>

- Other practical means are not reasonably available, and
- Pretreatment is provided by discharging to a modified type 2 catch basin (with a flow restrictor or oil/water separator) or water quality vault, and
- The discharge is upstream of a basic or enhanced stormwater treatment facility, and
- The storm sewer system owner/operator has granted approval.

Other practical means includes the use of decanting facilities and field decant sites that discharge to sanitary sewers or discharge to an approved stormwater treatment facility.

"Reasonably available" will be determined by the stormwater utility and by the circumstances, including such factors as distance, time of travel, load restrictions, and capacity of the stormwater treatment facility. Some jurisdictions may choose not to allow discharge back to the storm sewer system.

Limited field testing of flocculent aids has been conducted. While the use of flocculent aids is promising, sufficient testing has not been conducted to allow approval of any specific product or process. In general, the following conditions must be met for flocculent use to be approved:

- The flocculent must be non-toxic under circumstances of use and approved for use by the Department of Ecology.

- The decant must be discharged to an approved basic stormwater treatment facility, with sufficient capacity and appropriate design to handle the anticipated volume and pollutant loading.
- The discharge must be approved by the storm sewer system owner/operator.

Water removed from stormwater ponds, vaults and oversized catch basins may be returned to storm sewer system.

Stormwater ponds, vaults and oversized catch basins contain substantial amounts of liquid, which hampers the collection of solids and pose problems if the removed waste must be hauled away from the site. Water removed from these facilities may be discharged back into the pond, vault or catch basin provided:

- Clear water removed from a stormwater treatment structure may be discharged directly to a downgradient cell of a treatment pond or into the storm sewer system.
- Turbid water may be discharged back into the structure it was removed from if:
- The removed water has been stored in a clean container (eductor truck, Baker tank or other appropriate container used specifically for handling stormwater or clean water) and
- Sufficient settling time has elapsed (this may require 12 – 24 hours for the finer sediments typically collected in these treatment facilities.)
- The discharge must be approved by the storm sewer system owner/operator.

Vegetation management and structural integrity concerns sometimes require that the ponds be refilled as soon after solids removal as possible. For ponds and other systems relying on biological processes for waste treatment, it is often preferable to reuse at least some portion of the removed water.

The Site Evaluation

A street waste site evaluation is suggested as a method to identify spill sites or locations that are more polluted than normal.

The site evaluation will aid in determining if waste should be handled as dangerous waste and what to test for if dangerous waste is suspected. The site evaluation will also help to determine if the waste does not meet the requirements of the end users.

There are three steps to a site evaluation:

1. **Historical review** of the site for spills, previous contamination, nearby toxic cleanup sites, and dangerous waste and materials.

The historical review will be easier if done on an area wide basis prior to scheduling any waste collection. The historical review should be more thorough for operators who never collected waste at a site before. At a minimum, the historical review should include operator knowledge of the area's collection history or records kept from previous waste collections.

Private operators should ask the owner of the site for records of previous contamination and the timing of the most recent cleaning. Ecology's Hazardous Substance Information Office maintains a Toxic Release Inventory and a "Facility Site" webpage, tracking more than 15,000 sites. This information is available through the internet at http://www.wa.gov/ecology/iss/fsweb/fshome.html or by calling a toll-free telephone number (800-633-7585). The webpage allows anyone with web-access to search for facility information by address, facility name, town, zip code, SIC code, etc. It lists why the Department of Ecology is tracking each one (NPDES, TSCA, RCRA, Clean Air Act, etc.), as well as who to call within Ecology to find out more about the given facility.

2. **Area visual inspection** for potential contaminant sources, such as a past fire, leaking tanks and electrical transformers, and surface stains.

   The area around the site should be evaluated for contaminant sources prior to collection of the waste. The area visual inspection may be done either as part of multiple or as single site inspections. If a potential contaminant source is found, the waste collection should be delayed until the potential contaminant is assessed.

   A second portion of the area visual inspection is a subjective good housekeeping evaluation of the area. Locations with poor housekeeping commonly cut corners in less obvious places and should be inspected in greater detail for illegal dumping and other contamination spreading practices.

3. **Waste and container inspection** before and during collection.

   The inspection of the waste and catch basin or vault is the last and, perhaps most critical, step in the site evaluation.

   For example, if the catch basin or vault has an unusual color in or around it, then there is a strong possibility that something could have been dumped into it. Some colors to be particularly wary of are yellow-green from antifreeze dumping and black and(or) rainbow sheen from oil and(or) grease dumping. In addition, if any staining or corrosion is observed, then a solvent may have been dumped.

   Fumes are also good indicators of potential dangerous or dangerous waste. Deliberate smelling of catch basins should be avoided for worker safety, but suspicious odors may be encountered from catch basins thought to be safe. Some suspicious odors are rotten eggs (hydrogen sulfide is present), gasoline or diesel fumes, or solvent odors. If unusual odors are noted, contact a dangerous waste inspector before cleaning the basin.

Operator experience is the best guide to avoid collection of contaminated waste.

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Glossary

The following terms are provided for reference and use with this Manual. They shall be superseded by any other definitions for these terms adopted by ordinance, unless they are defined in a Washington State WAC or RCW.

Absorption	The penetration of a substance into or through another, such as the dissolving of a soluble gas in a liquid.
Adaptive management	The modification of management practices to address changing conditions and new knowledge. Adaptive management is an approach that incorporates monitoring and research to allow projects and activities, including projects designed to produce environmental benefits, to go forward in the face of some uncertainty regarding consequences. The key provision of adaptive management is the responsibility to change adaptively in response to new understanding or information after an action is initiated.
Adsorption	The adhesion of a substance to the surface of a solid or liquid; often used to extract pollutants by causing them to be attached to such adsorbents as activated carbon or silica gel. Hydrophobic, or water-repulsing adsorbents, are used to extract oil from waterways when oil spills occur. Heavy metals such as zinc and lead often adsorb onto sediment particles.
AKART	All Known, Available, and Reasonable methods of prevention, control, and Treatment. The most current methodology that can be reasonably required for preventing, controlling, or abating the pollutants associated with a discharge. The concept of AKART applies to both point and nonpoint sources of pollution. Best Management Practices (BMPs) typically applied to nonpoint source pollution controls are considered a subset of the AKART requirement. The Stormwater Management Manual for Easter Washington may be used as a guideline, to the extent appropriate, for developing best management practices to apply AKART for storm water discharges. AKART and Best Available Treatment (BAT) are roughly equivalent state and federal terms for the same concept.
Annual flood	The highest peak discharge, on average, which can be expected in any given year.
Antecedent moisture conditions	The degree of wetness of a watershed or within the soil at the beginning of a storm.
Applicable BMPs	As used in Chapters 2 and 8, applicable BMPs are those source control BMPs that are expected to be required by local governments at new development and redevelopment sites. Applicable BMPs will also be

	required if they are incorporated into NPDES permits, or if they are included by local governments in a stormwater program for existing facilities.
Aquifer	A geologic stratum containing ground water that can be withdrawn and used for human purposes.
Arid	Excessively dry; having insufficient rainfall to support agriculture without irrigation.
Arterial	A road or street primarily for through traffic. A major arterial connects an interstate highway to cities and counties. A minor arterial connects major arterials to collectors. A collector connects an arterial to a neighborhood. A collector is not an arterial. A local access road connects individual homes to a collector.
Average daily traffic (ADT)	The expected number of vehicles using a roadway is represented by the projected average daily traffic volume considered in designing the roadway. ADT counts must be estimated using "Trip Generation" published by the Institute of Transportation Engineers or from a traffic study prepared by a professional engineer or transportation specialist with expertise in traffic volume estimation. ADT counts shall be made for the design life of the project. For project sites with seasonal or varied use, evaluate the highest period of expected traffic impacts.
Bankfull discharge	A flow condition where streamflow completely fills the stream channel up to the top of the bank. In undisturbed watersheds, the discharge conditions occur on average every 1.5 to 2 years and controls the shape and form of natural channels.
Basic treatment	Treatment of stormwater with the goal of removing at least 80% of the solids present in the runoff using one of the treatment facilities or methods identified in Chapter 5. Basic treatment is required for all discharges that meet the thresholds in Chapter 2.2.5. Additional treatment to remove metals, oil or phosphorus may be required at some sites or for some receiving water bodies.
BAT	Best Available Technology. The most current technology available for controlling releases of pollutants to the environment. Major dischargers are required to use BAT unless it can be demonstrated that it is unfeasible for energy, environmental, or economic reasons. BAT and AKART are roughly equivalent federal and state terms for the same concept.
BCT	Best available Control Technology. All technologies and/or methods currently available for preventing releases of hazardous substances and demonstrated to work under similar site circumstances or through pilot studies, and applicable to the site at reasonable cost.

Bedrock	The more or less solid rock in place, either on or beneath the surface of the earth. It may be soft, medium, or hard and have a smooth or irregular surface.
Beneficial uses	Those water uses identified in state water quality standards that must be achieved and maintained as required under the Federal Clean Water Act. “Beneficial use” and “designated use” are often used interchangeably.
Berm	A constructed barrier of compacted earth, rock, or gravel. In a stormwater facility, a berm may serve as a vertical divider typically built up from the bottom.
Best available science	The technical provisions in the Stormwater Management Manual for Eastern Washington represent common provisions for the protection of waters of the state from adverse impacts of urban stormwater. Implementation of these provisions is necessary to minimize project specific and cumulative impacts to waters of the State. This Manual reflects the best available science and practices related to protection of water quality. The Manual will incorporate new information as it becomes available, and to allow for alternative practices that provide equal or greater protection for waters of the state.
Best Management Practices (BMPs)	The schedules of activities, prohibitions of practices, maintenance procedures, and structural and/or managerial practices approved by Ecology that, when used singly or in combination, prevent or reduce the release of pollutants and other adverse impacts to waters of Washington State.
Buffer zone	The area adjacent to a critical or sensitive area for which location and limits are described by federal, state, or local governments and intent is ensuring protection of the critical area by separating incompatible use from the critical or sensitive area.
Catch basin	A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.
Catchment	Surface drainage area.
Cation exchange capacity (CEC)	The amount of exchangeable cations that a soil can adsorb at pH 7.0.
Channel, constructed	Reconstructed natural channels or other channels or ditches constructed to convey surface water.

Channel, natural	Streams, creeks, or swales that convey surface water and groundwater and have existed long enough to establish a stable route and/or biological community.
Channel stabilization	Erosion prevention and stabilization of velocity distribution in a channel using vegetation, jetties, drops, revetments, and/or other measures.
Channel storage	Water temporarily stored in channels while enroute to an outlet.
Channelization	Alteration of a stream channel by widening, deepening, straightening, cleaning, or paving certain areas to change flow characteristics.
Check dam	Small dam constructed in a gully or other small watercourse to decrease the streamflow velocity, minimize channel scour, and promote deposition of sediment.
Commercial agriculture	Those activities conducted on lands defined in RCW 84.34.020(2), and activities involved in the production of crops or livestock for wholesale trade. An activity ceases to be considered commercial agriculture when the area on which it is conducted is proposed for conversion to a nonagricultural use or has lain idle for more than five (5) years, unless the idle land is registered in a federal or state soils conservation program, or unless the activity is maintenance of irrigation ditches, laterals, canals, or drainage ditches related to an existing and ongoing agricultural activity.
Compaction	The densification, settlement, or packing of soil in such a way that permeability of the soil is reduced. Compaction effectively shifts the performance of a hydrologic group to a lower permeability hydrologic group. For example, a group B hydrologic soil can be compacted and be effectively converted to a group C hydrologic soil in the way it performs in regard to runoff. Compaction may also refer to the densification of a fill by mechanical means.
Contractor Erosion and Spill Control Lead (CESCL)	The employee designated as the responsible representative in charge of erosion and spill control. The CESCL shall be qualified in construction site erosion and sediment control regulatory requirements and BMPs, and shall have thorough knowledge and understanding of the Construction Stormwater Pollution Prevention Plan (SWPPP) for the project site.
Conveyance	A mechanism for transporting water from one point to another, including pipes, ditches, and channels.
Conveyance system	The drainage facilities, both natural and man-made, which collect, contain, and provide for the flow of surface and stormwater from the highest points on the land down to a receiving water. The natural

elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. The human-made elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/detention facilities.

Critical area Any of the following areas and ecosystems: wetlands, areas with a critical recharging effect on aquifers used for potable water, fish and wildlife habitat conservation areas, frequently flooded areas, and geologically hazardous areas.

Custom design storm A synthetic rainfall event used to design stormwater treatment facilities in a particular jurisdiction. The design storm must be based upon a statistical analysis of local historical precipitation data, and reviewed and approved by the jurisdiction.

Dangerous waste According to RCW 70.105.010, any discarded, useless, unwanted, or abandoned substances, including, but not limited to, certain pesticides, or any residues or containers of such substances which are disposed of in such quantity or concentration as to pose a substantial, present, or potential hazard to human health, wildlife, or the environment. These wastes may have short-lived, toxic properties that may cause death, injury, or illness or have mutagenic, teratogenic, or carcinogenic properties; or be corrosive, explosive, flammable, or may generate pressure through decomposition or other means. See also *hazardous waste*.

Design storm A prescribed hyetograph or precipitation distribution, and the total precipitation amount for a specific duration recurrence frequency. The design storm is used to estimate runoff for a hypothetical rainstorm of interest or concern for the purposes of analyzing existing drainage, designing new facilities, or assessing other impacts of a proposed project on the flow of surface water. Design storms discussed in this Manual include the SCS Type IA and Type II storms, a modified Type IA storm, the regional storm, the long-duration storm, the short-duration storm, and custom design storms.

Design storm frequency The anticipated period in years that will elapse, based on average probability of storms in the design region, before a storm of a given intensity and/or total volume will recur. Thus a 10-year storm can be expected to occur on the average once every 10 years; the same storm has a 10 percent chance of occurring each year. Facilities designed to handle flows that occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

Detention	The release of stormwater runoff from the site at a slower rate than it is collected by the stormwater facility system, the difference being held in temporary storage.
Detention facility	An above or below ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system. There is little or no infiltration of stored stormwater.
Detention time	The theoretical time required to displace the contents of a stormwater treatment facility at a given rate of discharge (volume divided by rate of discharge).
Development	Means new development, redevelopment, or both. See definitions for each.
Discharge	Runoff leaving a new development or redevelopment via overland flow, built conveyance systems, or infiltration facilities. A hydraulic rate of flow, specifically fluid flow; a volume of fluid passing a point per unit of time, commonly expressed as cubic feet per second, cubic meters per second, gallons per minute, gallons per day, or millions of gallons per day.
Dispersion	Release of surface and stormwater runoff from a drainage facility system such that the flow spreads over a wide area, and is located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils.
Ditch	A long narrow excavation dug in the earth for drainage with its top width less than 10 feet at design flow.
Divide, Drainage	The boundary between one drainage basin and another.
Drain	A buried pipe or other conduit (closed drain). A ditch (open drain) for carrying off surplus surface water or ground water.
Drywell	A well completed above the water table so that its bottom and sides are typically dry except when receiving fluids. Drywells are designed to disperse water below the land surface and are commonly used for stormwater management in eastern Washington. See also UIC.
Effective impervious surface	Those impervious surfaces that are connected via sheet flow or a conveyance system to a drainage system. Most impervious areas are effective.
Emerging technology	Treatment technologies that have not been evaluated with approved protocols, but for which preliminary data indicate that they may provide a necessary function(s) in a stormwater treatment system.

Emerging technologies need additional evaluation to define design criteria to achieve, or to contribute to achieving, state performance goals, and to define the limits of their use.

Erodible or leachable materials Substances which, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include: erodible soils that are stockpiled, uncovered process wastes, manure, fertilizers, oily substances, ashes, kiln dust, and garbage dumpster leakage.

Erosion The wearing away of the land surface by running water, wind, ice, or other geological agents, including such processes as gravitational creep. Also, detachment and movement of soil or rock fragments by water, wind, ice, or gravity.

Erosion and sedimentation control (ESC) Any temporary or permanent measures taken to reduce erosion, control siltation and sedimentation, and ensure that sediment-laden water does not leave the site.

Erosion and sediment control facility A type of drainage facility designed to hold water for a period of time to allow sediment contained in the surface and stormwater runoff directed to the facility to settle out, so as to improve the quality of the runoff.

Evapotranspiration The collective term for the processes of evaporation and plant transpiration by which water is returned to the atmosphere.

Excavation The mechanical removal of earth material.

Exception Relief from the application of a Core Element to a project.

Existing condition The impervious surfaces, drainage systems, land cover, native vegetation and soils that exist at the site with approved permits and engineering plans when required. If sites have impervious areas and drainage systems that were built without approved permits, then the existing condition is defined as those that existed prior to the adoption of this Manual. These conditions can be verified by record aerial photography, or other methods.

First order stream An unbranched tributary. The tributary is a continuous perennial stream reach, meaning that the water table is always above the bottom of the stream channel during a year of normal precipitation and the perennial reach continues downstream to a confluence with another perennial stream.

Fish-bearing stream According to WAC 222-16-030: Type S, F and Np waters are fish habitat streams. Until these fish habitat water type maps are available, an interim water typing system applies (see WAC 222-16-031): Type 1, 2, 3, and 4 waters are fish habitat streams.

Flood — An overflow or inundation that comes from a river or any other source, including (but not limited to) streams, tides, wave action, storm drains, or excess rainfall. Any relatively high stream flow overtopping the natural or artificial banks in any reach of a stream.

Flood frequency — The frequency with which the flood of interest may be expected to occur at a site in any average interval of years. Frequency analysis defines the *x*-year flood as being the flood that will, over a long period of time, be equaled or exceeded on the average once every *x* years.

Flood routing — An analytical technique used to compute the effects of system storage dynamics on the shape and movement of flow represented by a hydrograph.

Flow duration — The aggregate time peak flows are at or above a particular flow rate of interest. For example, the amount of time peak flows are at or above 50% of the 2-year peak flow rate for a period of record.

Flow frequency — The inverse of the probability that the flow will be equaled or exceeded in any given year (the exceedance probability). For example, if the exceedance probability is 0.01 or 1 in 100, that flow is referred to as the 100-year flow.

Flow path — The route that stormwater runoff follows between two points of interest.

Forest practice — Any activity conducted on or directly pertaining to forest land and relating to growing, harvesting, or processing timber, including but not limited to: road and trail construction; harvesting, final and intermediate; precommercial thinning; reforestation; fertilization; prevention and suppression of diseases and insects; salvage of trees; and brush control.

Freeway — A multi-lane, arterial highway with full access control.

Frost-heave — The upward movement of soil surface due to the expansion of water stored between particles in the first few feet of the soil profile as it freezes. May cause surface fracturing of asphalt or concrete and(or) affect soil infiltration capacity.

Functions — The ecological (physical, chemical, and biological) processes or attributes of a water body without regard for their importance to society. Functions include food chain support, provision of ecosystem diversity and fish and wildlife habitat, floodflow alteration, ground water recharge and discharge, water quality improvement, and soil stabilization.

Groundwater Water in a saturated zone or stratum beneath the land surface or beneath a surface water body.

Groundwater recharge Inflow to a groundwater reservoir or aquifer.

Groundwater table The free surface of the ground water, that surface subject to atmospheric pressure under the ground, generally rising and falling with the season, the rate of withdrawal, the rate of restoration, and other conditions. It is seldom static.

Gully A channel caused by the concentrated flow of surface and stormwater runoff over unprotected erodible land.

Habitat The specific area or environment in which a particular type of plant or animal lives. An organism's habitat must provide all of the basic requirements for life and should be protected from harmful biological, chemical, and physical alterations.

Hazardous waste According to RCW 70.105.010 includes all dangerous and extremely hazardous waste, including substances composed of both radioactive and hazardous components. See also *dangerous waste*.

Hazardous substance According to RCW 70.105.010 any liquid, solid, gas, or sludge, including any material, substance, product, commodity, or waste, regardless of quantity, that exhibits any of the characteristics or criteria of *hazardous waste*. See also *dangerous waste*.

High ADT roadways and parking areas Any road with average daily traffic (ADT) greater than 30,000 vehicles per day; and parking areas with more than 100 trip ends per 1,000 square feet of gross building area or greater than 300 total trip ends are considered to be high-use traffic areas. Examples include commercial buildings with a frequent turnover of customers and other visitors.

High use sites Sites that generate high concentrations of oil due to high traffic turnover or the frequent transfer of oil and(or) other petroleum products. High-use sites are land uses where sufficient quantities of free oil are likely to be present, such that they can be effectively removed with special treatment. A high-use site is any one of the following:

- A road intersection with expected ADT of 25,000 vehicles or more on the main roadway and 15,000 vehicles or more on any intersecting roadway, excluding projects proposing primarily pedestrian or bicycle use improvements;

- A commercial or industrial site with an expected trip end count equal to or greater than 100 vehicles per 1,000 square feet of gross building area (best professional judgment should be used in comparing this criterion with the following criterion);
- A customer or visitor parking lot with an expected trip end count equal to or greater than 300 vehicles (best professional judgment should be used in comparing this criterion with the preceding criterion);
- Commercial on-street parking areas on streets with an expected total ADT count equal to or greater than 7,500;
- Fueling stations and facilities;
- A commercial or industrial site subject to petroleum storage and transfer in excess of 1,500 gallons per year, not including locations where heating fuel is routinely delivered to end users (heating fuel handling and storage facilities are subject to this definition);
- A commercial or industrial site subject to use, storage, or maintenance of a fleet of 25 or more diesel vehicles that are over 10 tons gross weight (trucks, buses, trains, heavy equipment, etc.);
- Maintenance and repair facilities for vehicles, aircraft, construction equipment, railroad equipment or industrial machinery and equipment;
- Outdoor areas where hydraulic equipment is stored;
- Log storage and sorting yards and other sites subject to frequent use of forklifts and(or) other hydraulic equipment;
- Railroad yards.

Highway A main public road connecting towns and cities.

Horton overland flow A runoff process whereby the rainfall rate exceeds the infiltration rate, so that the precipitation that does not infiltrate flows downhill over the soil surface.

HSPF Hydrological Simulation Program-Fortran. A continuous simulation hydrologic model that transforms an uninterrupted rainfall record into a concurrent series of runoff or flow data by means of a set of mathematical algorithms which represent the rainfall-runoff process at some conceptual level.

Hydrograph A graph of runoff rate, inflow rate, discharge rate, or another characteristic of a body of water during a specific period of time.

Hydrologic cycle The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Hydrologic soil groups A soil characteristic classification system defined by the U.S. Soil Conservation Service in which a soil may be categorized into one of four soil groups (A, B, C, or D) based upon infiltration rate and other properties:

Type A: Low runoff potential. Soils having high infiltration rates, even when thoroughly wetted, and consisting chiefly of deep, well drained to excessively drained sands or gravels. These soils have a high rate of water transmission.
Type B: Moderately low runoff potential. Soils having moderate infiltration rates when thoroughly wetted, and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.
Type C: Moderately high runoff potential. Soils having slow infiltration rates when thoroughly wetted, and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.
Type D: High runoff potential. Soils having very slow infiltration rates when thoroughly wetted, and consisting chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a hardpan, till, or clay layer at or near the surface, soils with a compacted subgrade at or near the surface, and shallow soils or nearly impervious material. These soils have a very slow rate of water transmission (Novotney and Olem, 1994).

Hydrology The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

Hydroperiod A seasonal occurrence of flooding and/or soil saturation; it encompasses depth, frequency, duration, and seasonal pattern of inundation.

Hyetograph A graph or table of percentages of total precipitation for a series of time steps representing the total time in which precipitation occurs.

Illicit discharge All non-stormwater discharges to stormwater drainage systems that cause or contribute to a violation of state water quality, sediment quality or groundwater quality standards, including, but not limited to, sanitary sewer connections, industrial process water, interior floor drains, car washing, and grey-water systems.

Impaired waters Water bodies not fully supporting their beneficial uses.

Impervious surface A hard surface area which either prevents or retards the entry of water into the soil mantle as under natural conditions prior to development. A hard surface area which causes water to run off the surface in greater quantities or at an increased rate of flow from the flow present under natural conditions prior to development. Common impervious surfaces include, but are not limited to, roof tops, walkways, patios, driveways, parking lots or storage areas, concrete or asphalt paving, gravel roads, packed earthen materials, and oiled, macadam or other surfaces which similarly impede the natural infiltration of stormwater. For purposes of determining whether thresholds for application of Core Elements are exceeded, open, uncovered retention or detention facilities shall not be considered as impervious surfaces. Open, uncovered retention or detention facilities shall be considered impervious surfaces for purposes of runoff modeling.

Improvements Improvement projects replace paved or other impervious areas with a better surface, and(or) in a way that enhances the traffic carrying capacity of a road or parking area, and(or) improves safety.

Industrial activities Material handling, transportation, or storage; manufacturing; maintenance; treatment; or disposal. Areas with industrial activities include plant yards, access roads and rail lines used by carriers of raw materials, manufactured products, waste material, or by-products; material handling sites; refuse sites; sites used for the application or disposal of process waste waters; sites used for the storage and maintenance of material handling equipment; sites used for residual treatment, storage, or disposal; shipping and receiving areas; manufacturing buildings; storage areas for raw materials, and intermediate and finished products; and areas where industrial activity has taken place in the past and significant materials remain and are exposed to stormwater.

Ineffective impervious surface Impervious surfaces on residential development sites where the runoff is not concentrated and is dispersed via sheet flow off the pavement, and then through at least one hundred feet of native vegetation before flowing into a drainage system. An example is a tennis court in the middle of a park.

Infiltration The downward movement of water from the land surface to the subsoil.

Infiltration facility (or system) A drainage facility designed to use the hydrologic process of surface and stormwater runoff soaking into the ground, commonly referred to as a percolation, to dispose of surface and stormwater runoff.

Infiltration rate The rate, usually expressed in inches per hour, at which water percolates, or moves downward through the soil profile. Short-term infiltration rates may be inferred from soil analysis or texture, or derived from field measurements. Long-term infiltration rates are affected by variability in soils and subsurface conditions at the site, the effectiveness of pretreatment or influent control, and the degree of long-term maintenance of the infiltration facility.

Interflow That portion of rainfall that infiltrates into the soil and moves laterally through the upper soil horizons until intercepted by a stream channel or until it returns to the surface, for example, in a roadside ditch, wetland, spring or seep. Interflow is a function of the soil system depth, permeability, and water-holding capacity.

Intermittent stream or intermittent channel A stream or portion of a stream that flows only in direct response to precipitation. Intermittent streams receive little or no water from springs and no long-continued supply from melting snow or other sources, and are dry for a large part of the year.

Irrigation ditch That portion of a designed and constructed conveyance system that serves the purpose of transporting irrigation water from its supply source to its place of use. This may include natural water courses or channels incorporated in the system design, but does not include the area adjacent to the water course or channel.

Isopluvial map A map with lines representing constant depth of total precipitation for a given return frequency.

Lag time The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff.

Land disturbing activity Any activity that results in movement of earth, or a change in the existing soil cover (both vegetative and non-vegetative) and/or the existing soil topography. Land disturbing activities include, but are not limited to clearing, grading, filling, and excavation. Compaction associated with stabilization of structures and road construction shall also be considered a land disturbing activity. Vegetation maintenance practices are not considered land-disturbing activity.

Leachable materials Those substances that, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include: erodible soils, uncovered process wastes, manure, fertilizers, oil substances, ashes, kiln dust, and garbage dumpster leakage.

Level pool routing The basic technique of storage routing used for sizing and analyzing detention storage and determining water levels for ponding water bodies. The level pool routing technique is based on the continuity equation: inflow minus outflow equals change in storage.

Local government Any county, city, town, or special purpose district having its own incorporated government for local affairs.

Long-duration design storm One of the four design storms consisting of two rainfall events separated by a dry period that were developed for climatic regions identified in eastern Washington. The storms were based on a statistical analysis of historical precipitation in Eastern Washington and have been adapted for use in this Manual as single-hump design storms consisting of only one continuous rainfall event. See "Modified SCS Type IA design storm" and "regional design storm." Also see further discussion in Appendix 4A.

Low ADT roadways and parking areas Urban roads with average daily traffic (ADT) fewer than 7,500 vehicles per day; rural roads and freeways with ADT less than 15,000 vehicles per day; and parking areas with less than 40 trip ends per 1,000 square feet of gross building area or fewer than 100 total trip ends per day are considered to be low-use traffic areas. Examples include: most residential parking and employee-only parking areas for small office parks or other commercial buildings.

Low flow channel An incised or paved channel from inlet to outlet in a dry basin which is designed to carry low runoff flows and(or) baseflow, directly to the outlet without detention.

Low impact development (LID) LID is an evolving approach to land development and stormwater management using the natural features of a site and specially designed BMPs to manage stormwater. LID involves assessing and understanding the site, protecting native vegetation and soils, and minimizing and managing stormwater at the source. LID practices appropriate for a variety of development types.

Low permeable liner A layer of compacted till or clay, or a geomembrane.

Maintenance Repair and maintenance includes activities conducted on currently serviceable structures, facilities, and equipment that involves no expansion or use beyond previously existing use, and resulting in no significant adverse hydrologic impact. It includes those usual activities taken to prevent a decline, lapse, or cessation in the use of structures and systems, and includes replacement of disfunctioning facilities, including cases where environmental permits require replacing an existing structure with a different type structure, as long as the functioning characteristics of the original structure are not changed. For example, replacing a collapsed, fish blocking, round culvert with a new box culvert under the same span, or width, of roadway. For further details on the application of this manual to various road management functions, see Chapter 2.1.2 through 2.1.4.

MEP Maximum Extent Practicable. The highest level of effectiveness that can be achieved through the use of personnel and best achievable technology. In determining what is the maximum extent practicable, Ecology shall consider, at a minimum, the effectiveness, engineering feasibility, commercial availability, safety, and the cost of the measures.

Metals Elements such as lead, mercury, copper, cadmium, and zinc which are of environmental concern, because they can be toxic to aquatic life and do not degrade over time.

Mitigation In the following order of preference, mitigation means:

(a) Avoiding the impact altogether by not taking a certain action or part of an action;
(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation, by using appropriate technology, or by taking affirmative steps to avoid or reduce impacts;
(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment;
(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and
(e) Compensating for the impact by replacing, enhancing, or providing substitute resources or environments.

Moderate ADT roadways and parking areas Urban roads with average daily traffic (ADT) between 7,500 and 30,000 vehicles per day; rural roads and freeways with ADT between 15,000 and 30,000 vehicles per day; and parking areas with between 40 and 100 trip ends per 1,000 square feet of gross building area or between 100 and 300 total trip ends per day are considered to be moderate-use traffic areas. Examples include visitor parking for small to medium commercial buildings with a limited number of daily customers.

Moderate use sites Moderate-use sites include “moderate ADT roadways and parking areas,” primary access points for high-density residential apartments, most intersections controlled by traffic signals, and transit center bus stops. These sites are expected to generate sufficient concentrations of metals that additional runoff treatment is needed to protect water quality in non-exempt surface waters.

Modified SCS Type IA design storm An adapted application of the synthetic SCS Type IA design storm to more closely reflect historical precipitation patterns in eastern Washington. Antecedent moisture conditions and precipitation depths are modified to reflect more typical conditions. See Chapter 4.2.3 for a complete description.

Modified wetland A wetland where physical, hydrological, or water quality characteristics have been purposefully altered for a management purpose, such as, by dredging, filling, forebay construction, and inlet or outlet control.

Monitoring The systematic collection of data by various methods for the purposes of understanding natural systems and features, evaluating the impacts of development proposals on such systems, and assessing the performance of mitigation measures imposed as conditions of development.

Municipality The term 'municipality' shall include every city, county, town, district, or other public agency thereof which is authorized by law to require the execution of public work, except drainage districts, diking districts, diking and drainage improvement districts, drainage improvement districts, diking improvement districts, consolidated diking and drainage improvement districts, consolidated drainage improvement districts, consolidated diking improvement districts, irrigation districts, or any such other districts as shall from time to time be authorized by law for the reclamation or development of waste or undeveloped lands.

Native growth protection easement An easement granted for the protection of native vegetation within a sensitive area or its associated buffer. The NPGE shall be recorded on the appropriate documents of title and filed with the county records division.

Native vegetation Vegetation comprised of plant species that are indigenous to Eastern Washington and which reasonably could have been expected to naturally occur on the site. Plant species classified as noxious weeds are excluded from this definition.

Natural conditions Surface water quality present before any human-caused pollution. When estimating natural conditions in the headwaters of a disturbed watershed it may be necessary to use the less disturbed conditions of a neighboring or similar watershed as a reference condition.

Natural location The location of those channels, swales, and other non-manmade conveyance systems, as defined by the first documented topographic contours existing for the subject property, either from maps or photographs, or such other means as appropriate. In the case of outwash soils with relatively flat terrain, no natural location of surface discharge may exist.

New development Land disturbing activities, including Class IV general forest practices that are conversions from timber land to other uses; structural

	development, including construction or installation of a building or other structure; creation of impervious surfaces; and subdivision, short subdivision and binding site plans, as defined and applied in Chapter 58.17 RCW. Projects meeting the definition of redevelopment shall not be considered new development.
Nonfish-bearing stream	According to WAC 222-16-030: Type Ns waters are nonfish habitat streams. Until these fish habitat water type maps are available, an interim water typing system applies (see WAC 222-16-031): Type 5 waters are nonfish habitat streams.
Non-pollutant generating impervious surfaces (NPGIS)	NPGIS are considered to be insignificant or low sources of pollutants in stormwater runoff. Roofs that are subject only to atmospheric deposition or normal heating, ventilation and air conditioning vents are considered NPGIS. The following may also be considered NPGIS: paved bicycle pathways and pedestrian sidewalks that are separated from and not subject to drainage from roads for motor vehicles, fenced fire lanes, infrequently used maintenance access roads, and "in-slope" areas of roads. Sidewalks that are regularly treated with salt or other deicing chemicals are not considered NPGIS.
Nonpoint source pollution	Pollution that enters any waters of the state from any dispersed land-based or water-based activities and does not result from discernible, confined, or discrete conveyances.
NPDES	National Pollutant Discharge Elimination System. A provision of the Clean Water Act which prohibits point-source discharges of pollutants into waters of the United States unless a special permit is issued and administered by the U.S. Environmental Protection Agency or by Ecology, as the delegated authority in Washington State. Municipal separate stormwater sewer systems are classified as point-source discharges.
NRCS Method	See SCS Method.
Nutrients	Essential chemicals needed by plants or animals for growth. Excessive amounts of nutrients can lead to degradation of water quality and algal blooms. Some nutrients can be toxic at high concentrations.
Off-line facilities	Water quality treatment facilities to which stormwater runoff is restricted to some maximum flow rate or volume by a flow-splitter.
Off-system storage	Facilities for holding or retaining excess flows over and above the carrying capacity of the stormwater conveyance system, in chambers, tanks, lagoons, ponds, or other basins that are not a part of the subsurface sewer system.

Oil/water separator A vault, usually underground, designed to provide a quiescent environment to separate oil from water.

On-line facilities Water quality treatment facilities which receive all of the stormwater runoff from a drainage area. Flows above the water quality design flow rate or volume are passed through at a lower percent removal efficiency.

On-site stormwater management BMPs Development and mitigation techniques that serve to infiltrate, disperse, and retain stormwater runoff on a project site.

Operational BMPs Operational BMPs are a type of source control BMP. They are schedules of activities, prohibition of practices, and other managerial practices to prevent or reduce pollutants from entering stormwater. Operational BMPs include formation of a pollution prevention team, good housekeeping, preventive maintenance procedures, spill prevention and clean-up, employee training, inspections of pollutant sources and BMPs, and record keeping. They can also include process changes, raw material/product changes, and recycling wastes.

Ordinary high water mark The line on the shore established by the fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of soil destruction on terrestrial vegetation, or the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding area. The ordinary high water mark is found by examining the bed and banks of a stream and ascertaining where the presence and action of waters are so common and usual, and so long maintained in all ordinary years, as to mark upon the soil a character distinct from that of the abutting upland, in respect to vegetation. In any area where the ordinary high water mark cannot be found, the line of mean high water shall substitute. In any area where neither can be found, the channel bank shall be substituted. In braided channels and alluvial fans, the ordinary high water mark or substitute shall be measured so as to include the entire stream feature.

Orifice An opening with closed perimeter, usually sharp-edged, and of regular form in a plate, wall, or partition through which water may flow, generally used for the purpose of measurement or control of water.

Outlet Point of water disposal from a stream, river, lake, tidewater, or artificial drain.

Outlet channel A waterway constructed or altered primarily to carry water from man-made structures, such as terraces, tile lines, and diversions.

Overflow A pipeline or conduit device, together with an outlet pipe, that provides for the discharge of portions of combined sewer flows into

	receiving waters or other points of disposal, after a regular device has allowed the portion of the flow which can be handled by interceptor sewer lines and pumping and treatment facilities to be carried by and to such water pollution control structures.
Overflow rate	Detention basin release rate divided by the surface area of the basin. It can be thought of as an average flow rate through the basin.
Overtopping	Flow over the limits of a containment or conveyance element.
Particle size	The effective diameter of a particle as measured by sedimentation, sieving, or micrometric methods.
Peak discharge	The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.
Peak-shaving	Controlling post-development peak discharge rates to pre-development levels by providing temporary detention in a BMP.
Percolation	The movement of water through soil.
Percolation rate	The rate, often expressed in minutes per inch, at which clear water, maintained at a relatively constant depth, will seep out of a standardized test hole that has been previously saturated. The term percolation rate is often used synonymously with infiltration rate or short-term infiltration rate.
Perennial stream	A stream reach that does not go dry during a year of normal precipitation: the elevation of the water table is always above the bottom of the stream channel during a year of normal precipitation.
Permanent Stormwater Control (PSC) Plan	A plan which includes permanent Best Management Practices (BMPs) for preventing and controlling pollution of stormwater runoff. These BMPs will remain in place after construction and(or) land disturbing activity has been completed.
Permeable soils	Soil materials with a sufficiently rapid infiltration rate so as to greatly reduce or eliminate surface and stormwater runoff. These soils are generally classified as SCS hydrologic soil types A and B.
Pesticide	A general term used to describe any substance - usually chemical - used to destroy or control organisms; includes herbicides, insecticides, algicides, fungicides, and others. Many of these substances are manufactured and are not naturally found in the environment. Others, such as pyrethrum, are natural toxins that are extracted from plants and animals.

pH A measure of the alkalinity or acidity of a substance which is conducted by measuring the concentration of hydrogen ions in the substance. A pH of 7.0 indicates neutral water. A 6.5 reading is slightly acid.

Physiography Characteristics of the natural physical environment (including hills).

Plan Approval Authority The department within a local government that has been delegated authority to approve stormwater site plans.

Plat A map or representation of a subdivision showing the division of a tract or parcel of land into lots, blocks, streets, or other divisions and dedications.

Point discharge The release of collected and/or concentrated surface and stormwater runoff from a pipe, culvert, or channel.

Point of compliance The location at which compliance with a discharge performance standard or a receiving water quality standard is measured.

Pollution Contamination or other alteration of the physical, chemical, or biological properties of waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters; or such discharge of any liquid, gaseous, solid, radioactive or other substance into any waters of the state as will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life.

Pollutant-generating impervious surface (PGIS) PGIS are considered to be significant sources of pollutants in stormwater runoff. Such surfaces include those that are subject to vehicular use, industrial activities, or storage of erodible or leachable materials that receive direct rainfall, or run-on or blow-in of rainfall. Metal roofs are considered to be PGIS, unless coated with an inert, non-leachable material. Roofs that are subject to venting of manufacturing, commercial, or other indoor pollutants are also considered PGIS. A surface, whether paved or not, shall be considered PGIS if it is regularly used by motor vehicles. The following are considered regularly-used surfaces: roads, unvegetated road shoulders, bike lanes within the traveled lane of a roadway, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways.

Pollution-generating pervious surface (PGPS) Any non-impervious surface subject to use of pesticides and fertilizers, or loss of soil. Typical PGPS include lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields.

Pre-developed condition The native vegetation and soils that existed at a site prior to the influence of Euro-American settlement. Jurisdictions may choose to require that either the pre-developed condition or the "existing condition" be used to calculate runoff volumes to be compared to the runoff generated under the "proposed development condition." Because there is limited information available to identify and confirm actual pre-developed conditions for many areas of eastern Washington, jurisdictions may choose to apply a reasonably determined set of conservative curve numbers for use in determining the runoff volume compared to that under the proposed development condition.

Prediction For the purposes of this document an expected outcome based on the results of hydrologic modeling and/or the judgment of a trained professional civil engineer or geologist.

Preservation/ maintenance A preservation or maintenance project is defined as preserving/ protecting infrastructure by rehabilitating or replacing existing structures to maintain operational and structural integrity, and for the safe and efficient operation of the facility. Traffic area maintenance projects do not increase the traffic carrying capacity of a roadway or parking area.

Pretreatment The removal of material such as solids, grit, grease, and scum from flows prior to physical, biological, or physical treatment processes to improve treatability. Pretreatment may include screening, grit removal, settling, oil/water separation, or application of a basic treatment BMP prior to infiltration.

Process wastewater The used water and solids from an industrial source. This water should be directed to a treatment facility and kept separate from the stormwater generated from the site.

Project Any proposed action to alter or develop a site; or the proposed action of a permit application or an approval which requires drainage review.

Project site That portion of a property, properties, or right of way subject to land disturbing activities, and new or replaced impervious surfaces.

Proposed development condition The impervious surfaces, drainage systems, land cover, native vegetation and soils that are proposed to exist at the site at the completion of the project (complete build-out).

Properly Functioning Soil System (PFSS) A natural system that has not been disturbed or modified, or an engineered soil/landscape system designed to meet certain criteria.

Rare, threatened, or endangered species Native plant or animal species listed in rule by the Washington State Department of Fish and Wildlife pursuant to RCW 77.12.020 as threatened (WAC 232-12-011) or endangered (WAC 232-12-014), or that are listed as threatened or endangered species under the federal Endangered Species Act, 16 U.S.C. 1533. Rare plant or animal species are regionally relatively uncommon, are nearing endangered status, or whose existence is in immediate jeopardy and is usually restricted to highly specific habitats. Rare species are unofficial species of concern.

Rational Method A method of computing storm drainage flow rates (Q) by use of the formula Q = CIA, where C is a coefficient describing the physical drainage area, I is the rainfall intensity, and A is the area. In this Manual, use of the Rational Method is limited to sizing only certain types of runoff treatment facilities, drywells, and conveyance; see Chapter 4.

Reach A length of a water body with uniform characteristics.

Receiving waters Bodies of water or surface water systems to which surface runoff is discharged via a point source of stormwater or via sheet flow.

Recommended BMPs As used in Chapters 2 and 8, recommended BMPs are those BMPs that are not expected to be mandatory by local governments at new development and redevelopment sites. However, they may improve pollutant control efficiency, and may provide a more comprehensive and environmentally effective stormwater management program.

Redevelopment On a site that is already substantially developed, the replacement or improvement of impervious surfaces, including buildings and other structures, and replacement or improvement of impervious parking and road surfaces, that is not part of a routine maintenance activity. (Any new impervious surfaces created by a redevelopment project are subject to the requirements for new development.) See Chapter 2.1.2 for a complete detail of requirements for redevelopment projects.

Regional design storm A custom synthetic design storm taken from the *long-duration design storm* which was based upon a statistical analysis of historical precipitation data from gaging stations in eastern Washington. The four regional storms consist of the second, or larger precipitation event of the two contained in each of four the long-duration storms identified for the four climatic regions of eastern Washington.

Regional detention facility A stormwater quantity control structure designed to correct existing surface water runoff problems of a basin or subbasin. The area downstream has been previously identified as having existing or predicted significant and regional flooding and/or erosion problems. This term is also used when a detention facility is sited to detain stormwater runoff from a number of new developments or areas within a catchment.

Release rate	The computed peak rate of surface and stormwater runoff from a site.
Replaced impervious surface	For structures, the removal and replacement of any exterior impervious surfaces or foundation. For other impervious surfaces, the removal down to bare soil, or base course and replacement.
Residential density	The number of dwelling units per unit of surface area. Net density includes only occupied land. Gross density includes unoccupied portions of residential areas, such as roads and open space.
Retention	The process of collecting and holding surface and stormwater runoff with no surface outflow.
Retention/detention (R/D) facility	A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, and/or infiltration into the ground; or to hold surface and stormwater runoff for a short period of time and then release it to the surface and stormwater management system.
Retrofitting	The renovation of an existing structure or facility to meet changed conditions or to improve performance.
Return frequency or recurrence interval	A statistical term for the average expected time interval between events (e.g., flows, floods, droughts, or rainfall) that equal or exceed given conditions.
Runoff	Water originating from rainfall and other precipitation that is found in drainage facilities, rivers, streams, springs, seeps, ponds, lakes, and wetlands, as well as shallow ground water. As applied in this manual, it also means the portion of rainfall or other precipitation that becomes surface flow and interflow.
Saturation point	In soils, the point at which a soil or an aquifer will no longer absorb any amount of water without losing an equal amount.
SCS	Soil Conservation Service (now the Natural Resources Conservation Service), U.S. Department of Agriculture.
SCS Method	A single-event hydrologic analysis technique for estimating runoff based on the Curve Number method. The Curve Numbers are published by the SCS, now NRCS, in *Urban Hydrology for Small Watersheds, 55 TR, June 1986*. Since the change in the agency's name, the method may be referred to as the NRCS Method.
Seasonal stream	A stream or segments of a stream that normally goes dry during a year of normal rainfall. Seasonal streams often receive water from springs and/or long-continued water supply from melting snow or other sources.

Sediment	Fragmented material that originates from weathering and erosion of rocks or unconsolidated deposits, and is transported by, suspended in, or deposited by water.
Semi-arid	Characterized by light rainfall; having from about 10 to 20 inches of annual precipitation.
Sensitive area	Any area designated by a federal, state, or local government to have unique or important environmental characteristics that may require special additional protective measures. These areas include, but are not limited to: wetlands and their buffer zones, stream riparian areas, well-head protection areas, and geologic hazard areas. See also *critical area*.
Settleable solids	Those suspended solids in stormwater that separate by settling when the stormwater is held in a quiescent condition for a specified time.
Sheet flow	Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.
Short-duration design storm	A synthetic three-hour custom design storm that represents rainfall during a typical summer thunderstorm in eastern Washington. The storm is based upon a statistical analysis of historical precipitation data from gaging stations in eastern Washington.
Siltation	The process by which a river, lake, or other waterbody becomes clogged with sediment. Silt can clog gravel beds and prevent successful salmon spawning.
Site	The area defined by legal boundaries of a parcel or parcels of land that is (are) subject to new development or redevelopment. For road projects, the length of the project site and the right-of-way boundaries define the site.
Soil stabilization	The use of measures, such as rock lining, vegetation or other engineering structures, to prevent the movement of soil when loads are applied to the soil.
Sorption	The physical or chemical binding of pollutants to sediment or organic particles.
Source control BMP	A structure or operation intended to prevent pollutants from coming into contact with stormwater through physical separation of areas or careful management of activities that are sources of pollutants. This manual separates source control BMPs into two types. *Structural source control BMPs* are physical, structural, or mechanical devices or facilities that are intended to prevent pollutants from entering stormwater. *Operational BMPs* are non-structural practices that

prevent or reduce pollutants from entering stormwater. See Chapter 8 for details.

Spill control device	A tee section or turn down elbow designed to retain a limited volume of pollutant that floats on water, such as oil or antifreeze. Spill control devices are passive and must be cleaned-out for the spilled pollutant to actually be removed.
Spillway	A passage such as a paved apron or channel for surplus water over or around a dam or similar obstruction. An open or closed channel, or both, used to convey excess water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate the discharge of excess water.
Storage routing	A method to account for the attenuation of peak flows passing through a detention facility or other storage feature.
Storm drain system	The system of gutters, pipes, streams, or ditches used to carry surface and stormwater from surrounding lands to streams or lakes.
Storm sewer	A sewer that carries stormwater and surface water, street wash and other wash waters or drainage, but excludes sewage and industrial wastes. Also called a "storm drain."
Stormwater	That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows, via overland flow, interflow, pipes and other features of a stormwater drainage system, into a defined surface water body or a constructed infiltration facility.
Stormwater drainage system	Constructed and natural features which function together as a system to collect, convey, channel, hold, inhibit, retain, detain, infiltrate, divert, treat, or filter stormwater.
Stormwater facility	A constructed component of a stormwater drainage system designed or constructed to perform a particular function or multiple functions. Stormwater facilities include, but are not limited to: pipes, swales, ditches, culverts, street gutters, detention ponds, retention ponds, constructed wetlands, infiltration devices, catch basins, oil/water separators, and biofiltration swales.
Stormwater Management Manual for Eastern Washington (Stormwater Manual, or "Manual")	This Manual, as prepared by Ecology, contains BMPs to prevent, control, or treat pollution in stormwater, and reduce other stormwater-related impacts to waters of the state. The Stormwater Manual is intended to provide guidance on measures necessary in eastern Washington to control the quantity and quality of stormwater runoff from new development and redevelopment.

Stormwater Site Plan (SSP)	The comprehensive report containing all of the technical information and analysis necessary for regulatory agencies to evaluate a proposed new development or redevelopment project for compliance with stormwater requirements. Contents of the Stormwater Site Plan will vary with the type and size of the project and individual site characteristics. It includes a Construction Stormwater Pollution Prevention Plan (Construction SWPPP) and a Permanent Stormwater Control Plan (PSC Plan). Guidance on preparing a SSP is provided in Chapter 3.
Stream	An area where surface waters flow sufficiently to produce a defined channel or bed. A defined channel or bed is an area that demonstrates clear evidence of the passage of water including, but not limited to, hydraulically sorted sediments, or the removal of vegetative litter or loosely rooted vegetation by the action of moving water. The channel or bed need not contain water year-round. This definition is not meant to include irrigation ditches, canals, stormwater runoff devices or other entirely artificial watercourses, unless they are used to convey streams naturally occurring prior to construction. Those topographic features that resemble streams but have no defined channels (i.e., swales) shall be considered streams when hydrologic and hydraulic analyses done pursuant to a development proposal predict formation of a defined channel after development.
Stream order	A dimensionless basin characteristic indicating the degree of stream channel branching, used in geomorphology and runoff studies. An nth order stream is formed by two or more streams of (n-1) order: a second order stream exists below the confluence of two first order streams, a third order stream below the confluence of two second order streams, and so on.
Subbasin	A drainage area that drains to a water-course or water body named and noted on common maps and which is contained within a basin.
Susceptibility	The ease with which contaminants can move from the land surface to the aquifer, based solely on the types of surface and subsurface materials in the area. Susceptibility usually defines the rate at which a contaminant will reach an aquifer unimpeded by chemical interactions with the vadose zone media.
Suspended solids	Organic or inorganic particles suspended in and carried by the water. The term includes sand, mud, and clay particles (and associated pollutants), as well as solids in stormwater.
Swale	A shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than one foot.

Tightline	A continuous length of pipe that conveys water from one point to another (typically down a steep slope) with no inlets or collection points in between.
Time of concentration	The time period necessary for surface runoff to reach the outlet of a subbasin from the hydraulically most remote point in the tributary drainage area.
TMDL	Total Maximum Daily Load, also known as a "Water Cleanup Plan." A calculation of the maximum amount of a pollutant that a water body can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the water body can be used for the purposes the state has designated. The calculation must also account for seasonable variation in water quality. Water quality standards are set by states, territories, and tribes. They identify the uses for each water body, for example, drinking water supply, contact recreation (swimming), and aquatic like support (fishing), and the scientific criteria to support that use. The Clean Water Act, section 303, establishes the water quality standards and TMDL programs.
Topography	General term to include characteristics of the ground surface, such as plains, hills, mountains, degree of relief, steepness of slopes, and other physiographic features.
Travel time	The estimated time for surface water to flow between two points of interest.
Treatment BMP	A BMP that is intended to remove pollutants from stormwater. A few examples of treatment BMPs are detention ponds, oil/water separators, biofiltration swales, and constructed wetlands.
Treatment liner	A layer of soil that is designed to slow the rate of infiltration and provide sufficient pollutant removal so as to protect groundwater quality.
Treatment train	A combination of two or more treatment facilities connected in series.
Trip end	The expected number of vehicles using a parking area is represented by the projected trip end counts for the parking area associated with a proposed land use. Trip end counts must be estimated using "Trip Generation" published by the Institute of Transportation Engineers or from a traffic study prepared by a professional engineer or transportation specialist with expertise in traffic volume estimation. Trip end counts shall be made for the design life of the project. For project sites with seasonal or varied use, evaluate the highest period of

expected traffic impacts.

Turbidity Dispersion or scattering of light in a liquid, caused by suspended solids and other factors; commonly used as a measure of suspended solids in a liquid.

UIC Underground Injection Control. A federal regulatory program established to protect underground sources of drinking water from UIC well discharges. A UIC well is defined as a bored, drilled, or driven shaft whose depth is greater than the largest surface dimension; or a dug hole whose depth is greater than the largest surface dimension; or an improved sinkhole; or a subsurface fluid distribution system which includes an assemblage of perforated pipes, drain tiles, or other similar mechanisms intended to distribute fluids below the surface of the ground. Examples of UIC wells or a subsurface infiltration systems are drywells, drain fields, catch basins, pipe or french drains, and other similar devices that discharge to ground.

Upgrade The replacement of paved areas with a better surface or in a way that enhances the traffic capacity of the road.

Urban runoff Stormwater from streets and adjacent domestic or commercial properties that may carry pollutants of various kinds into storm sewers or drywells and/or receiving waters.

Variance See Exception.

Water body segment A stream reach or portion of a water body generally having the same characteristics. Water body segments may be defined by reaches between confluences with major tributaries or by section lines on a 1:24,000 scale topographical map.

Watershed The land area that drains into a stream, lake, or other body of water. An area of land that contributes runoff to one specific delivery point. Large watersheds may be composed of several smaller subwatersheds, each of which contributes runoff to different runoff locations that ultimately combine at a common delivery point or receiving water. The words “watershed” and “basin” are often used interchangeably.

Water quality A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

Water quality criteria Levels or measures of water quality considered necessary to protect a beneficial use.

Water quality standards	Minimum requirements of purity of water for various uses; levels or measures of water quality considered necessary to protect a beneficial use. In Washington State, the Department of Ecology sets water quality standards.
Waters of the state	State waters include lakes, rivers, ponds, streams, inland waters, underground waters, salt waters, wetlands, and all other surface waters and watercourses within the jurisdiction of the state of Washington.
Water table	The upper surface or top of the saturated portion of the soil or bedrock layer, indicating the uppermost extent of groundwater.
Wetlands	Areas characterized by saturated or nearly saturated soils most of the year that form an interface between terrestrial (land-based) and aquatic environments. Wetlands include marshes around lakes or ponds and along river or stream channels.